# Calibration of VISSIM to the traffic conditions of Khobar and Dammam, Saudi Arabia

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Civil Engineering

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## Abstract

Simulation modeling is an increasingly popular and effective tool for analyzing transportation problems with the least cost. Recent advancements in computer technology have led to the development of high fidelity microscopic simulation models. For any simulation study, model calibration is a crucial step for obtaining any representative results from the analysis.

The main objective of this study is to calibrate and validate the microscopic traffic simulation model VISSIM to the traffic conditions of Khobar and Dammam, Saudi Arabia. VISSIM is a German microscopic simulation model that is beginning to see increased use within the United States and in many other major countries. It is one of the few comprehensive microscopic traffic simulators covering a wide range of traffic situations including traffic and transit on urban roads and motorways.

To achieve this main objective several default values for the parameters such as number of observed vehicles, additive and multiplicative part of desired safety distance, amber signal decision and distance required in changing lane were modified to replicate field conditions. The results with these modified values showed no discrepancy between the model simulation MOE's and the field observed MOE's.

In order to validate the calibrated model, it has been applied on another network chosen in Dammam city using a different data set. Model validation was regarded as a final stage to investigate if each component adequately reproduces observed travel characteristics and overall performance of the model is within an acceptable error. The results of the validation showed that the difference between the field observed MOE's and the VISSIM simulation results are within the acceptable range.

# CALIBRATION OF VISSIM TO THE TRAFFIC CONDITIONS OF KHOBAR AND DAMMAM, SAUDI ARABIA

BY

**SYED ANEES AHMED**

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# THESIS ABSTRACT

**Name**: Syed Anees Ahmed

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Simulation modeling is an increasingly popular and effective tool for analyzing transportation problems that are not amendable to study by other means. Recent advancements in computer technology have led to the development of high fidelity microscopic simulation models. For any simulation study, model calibration is a crucial step for obtaining any representative results from the analysis.

The main objective of this study is to calibrate and validate the microscopic traffic simulation model VISSIM to the traffic conditions of Khobar and Dammam, Saudi Arabia. VISSIM is a German microscopic simulation model that is beginning to see increased use within the United States and in many other major countries. It is one of the few comprehensive microscopic traffic simulators covering a wide range of traffic situations including traffic and transit on urban roads and motorways.

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# THESIS ABSTRACT (ARABIC)

## ملخص الرسالة

**الاســـــــــم**: [اكتب اسمك]

**عنوان الرسالة**: [اكتب عنوان الرسالة]

**التخصـــــــص**: [اكتب تخصصك]

**تاريخ التخــرج**: [اكتب الشهر والسنة]

[انقر واكتب ملخص الرسالة]

# CHAPTER 1

# INTRODUCTION

## 1.1 General Introduction

Simulation of traffic as a tool for investigating traffic systems has increased in popularity over the last decades. A large portion of this rise in popularity can be tracked back to the rapid development in the personal computer area. Fast personal computers have made it possible to develop advanced traffic micro-simulation software packages. Traffic simulation is a powerful and cost-efficient tool for traffic planning and designing, testing different alternatives and evaluating traffic management schemes. The simulation model enables the engineer to predict the outcomes of a proposed change to the traffic system before it is implemented, and to evaluate the merits of competing designs. This is a very important consideration, given the impacts that such projects can have on nearby communities and on local economies. For the simulation model to correctly predict the system response however, it must first be shown to reproduce the existing traffic condition. The procedure by which the parameters of the model are adjusted so that the simulated response agrees with the measured field conditions is what is known as model calibration.

Simulation models are generally classified into macroscopic and microscopic models, depending on their level of modeling detail. Macroscopic simulation models describe the traffic flow in a road network using entities such as density, flow and average speed. Microscopic simulation models describe the behavior of the individual drivers as they react to their perceived environments. The aggregate response in the latter case is the result of interactions among many driver/vehicle entities in the network. The output of traffic simulation models is however to a large extent independent of the level of detail used in the modeling. Most of the interesting results are macroscopic traffic measures such as average travel time between two points or average speed. Microscopic results such as driving courses of events are of interest in, for example, emission modeling. Macroscopic simulation models are, due to the lower model resolution, able to deal with much larger networks than micro-simulation models (Gomes G. *et al.* 2003).

Microscopic simulation is used in cases where one is interested in the dynamics of the traffic system or if information of microscopic traffic measures is needed. Typical applications of microscopic simulation programs include analysis of the impacts of different network designs, evaluation of ITS (Intelligent Transportation Systems) applications and emission modeling which require detailed information on driving course of events. Required input to a microscopic simulation model is a road network and input flows and turning proportions at each intersection. Other input data may include for example control plans for signalized intersections or information about stop or yield signs at uncontrolled intersections. Common output is, as mentioned above, macroscopic measures such as average traveling time and speed.

Today, the number of simulation models is vast and the simulation approach and model application utilized in these models are to a large extent differentiated. There is therefore an obvious need for calibration and validation of traffic microscopic simulation models. All traffic microscopic simulation models use a very large number of parameters that have to be calibrated in order to achieve representative results. The calibration work increases fast with the number of parameters.

Several well-known simulation models such as Transyt-7F, AIMSUN, PARAMICS, SYNCHRO, SIMTRAFFIC, CORSIM, WATSIM, TRANSIM, etc. that are currently used in the world has been studied. Their comparisons with respect to the VISSIM simulation model are reviewed and discussed in the next chapter (Literature review). Based on the comparisons it was found that the VISSIM model is the most appropriate simulation model because it is the one which was extensively and successfully used in many countries under various traffic conditions and driving behaviors. In addition to this, VISSIM is used for the evaluation of various alternatives and it offered excellent modeling of complicated networks and superior graphics.

This study is to calibrate and validate the microscopic traffic simulation software VISSIM. The study area for the calibration purpose is taken from Khobar and the study area for the validation purpose is taken from Dammam. These cities are largest cities and in the center of the Eastern Province of Saudi Arabia. The study area maps are depicted below in Figure 1.1 and Figure 1.2.

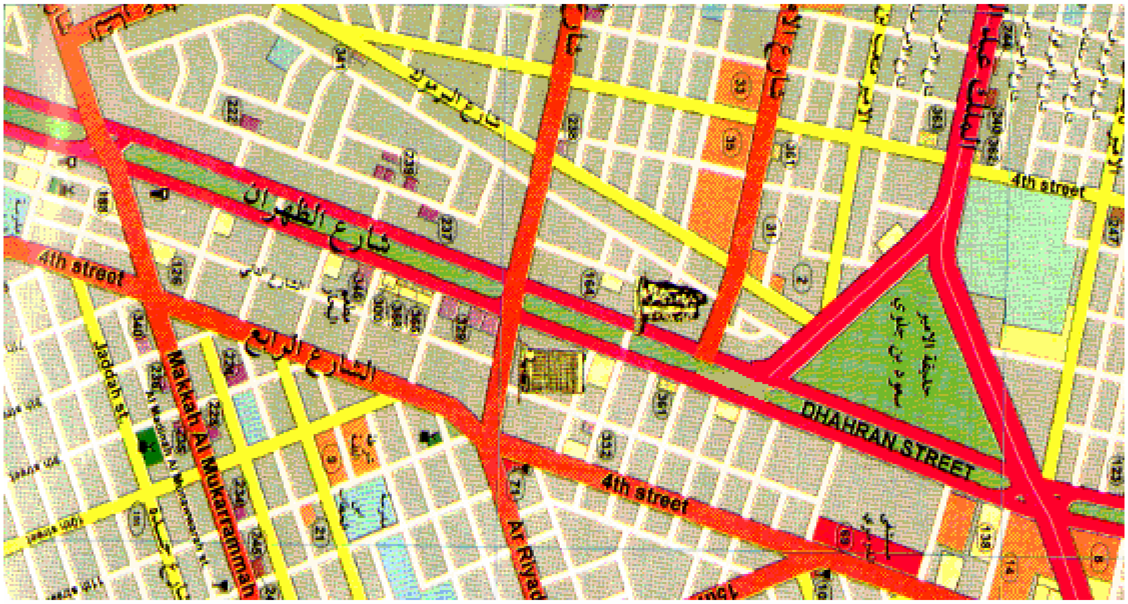


**Figure 1.1: Study area for Calibration (Dhahran Street, Khobar)**

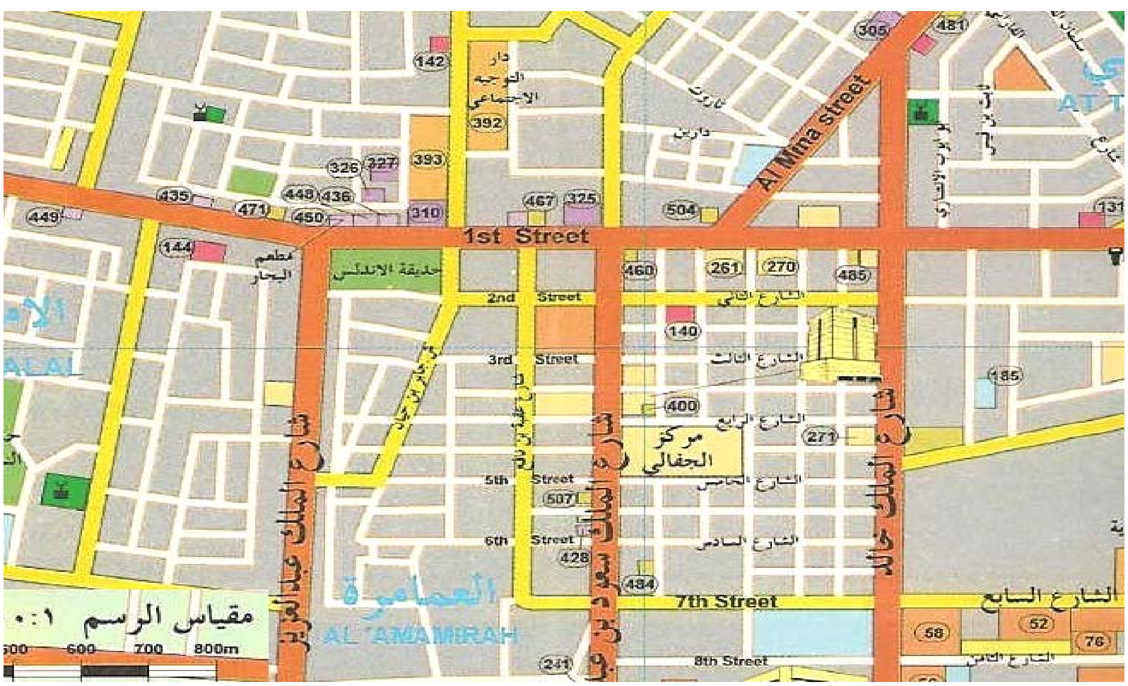


**Figure 1.2: Study area for Validation (1st Street, Dammam)**

## 1.2 The Problem Statement

As transportation systems have become more complex and frequently congested, simulation modeling has gained recognition as an effective approach for quantifying traffic operations. This in turn leads to increase travel time causing delay and unnecessary stops. Traffic simulation packages like VISSIM and other models can address these types of network issues, and are frequently used as tools for analyzing traffic. However, there is little information available to the analysts applying these models about the most appropriate models to use, or even detailed information about the accuracy of individual models.

Unfortunately, the user manuals for simulation models provide little or no information about the source or appropriateness of the default parameters, nor do they provide substantial guidance on how the user should modify these parameters for different types of traffic conditions. Therefore, the user has a greater responsibility for ensuring that appropriate changes are made that are based on field-measured data and not exclusively on engineering judgment.

There are many simulation models that can be used for traffic network analysis; and to use any of these models we need to test its applicability for the local traffic conditions. In each of these models, there are a number of parameters that represents the driving behavior and traffic conditions in the country where the model was originally introduced and calibrated. There is therefore an obvious need for calibration and validation of these models in order to achieve representative results. Calibration is the process in which the model parameters of the simulator are optimized to the extent possible for obtaining a close match between the simulated and the actual traffic measurements, which primarily include volume, speed and travel time. Generally, calibration is an iterative process in which the engineer adjusts the simulation model parameters until the results produced by the simulator match field measurements; the comparison part is often referred to as validation.

State-of-the-art VISSIM simulation model has been selected to calibrate for the local traffic conditions of Saudi Arabia. VISSIM is a German microscopic simulation model that is beginning to see increased use within the United States. It is one of the few comprehensive microscopic traffic simulators covering a wide range of traffic situations including traffic and transit on urban roads and motorways. It is a multipurpose simulator aimed for technical staff at cities responsible for signal control, transit operators, city planners and researchers to evaluate the influence of new control and vehicle technologies. In a sense it is innovative to collect a variety of real-world traffic problems, apply long-term research work and put it together to form a software package. To use VISSIM simulation model for the local traffic conditions of Khobar and Dammam, Saudi Arabia its applicability in this county need to be tested.

## 1.3 Objectives

The main objectives of this study are as follows:

1. To explore the similarities and differences in traffic performance and driving behavior on urban networks between the Germany and Saudi Arabia.
2. To perform a parametric analysis on the VISSIM simulation model to determine which default parameters are need to be modified.
3. To calibrate the VISSIM simulation model to replicate the local traffic conditions of Khobar, Saudi Arabia.
4. To validate the calibrated VISSIM simulation model by implementing it on another arterial located in Dammam, Saudi Arabia.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

In general, simulation is defined as dynamic representation of some part of the real world achieved by building a computer model and moving it through time (Drew 1968). Computer models are widely used in traffic and transportation system analysis. The use of computer simulation started when D.L. Gerlough published his dissertation: "Simulation of freeway traffic on a general-purpose discrete variable computer" at the University of California, Los Angeles, in 1955 (Kallberg 1971). From those times, computer simulation has become a widely used tool in transportation engineering with a variety of applications from scientific research to planning, training and demonstration.

The five driving forces behind this development are the advances in traffic theory, in computer hardware technology and in programming tools, the development of the general information infrastructure, and the society's demand for more detailed analysis of the consequences of traffic measures and plans.

The basic application areas of simulation have mainly remained the same, but the applications have grown in size and complexity. In the 1990's demand analysis through simulation has emerged as a new application area. New programming techniques and environments, like object-oriented programming and virtual reality tools are coming to common use. Integrated use of several programs and the applications of parallel computing and GIS databases are some of the latest trends in traffic systems simulation. New ideas, like cellular automata and rule-based simulation with discrete variables have also proven their strength.

In the following, it was tried to give an overall view of the development, present use and future directions of simulation in road traffic planning and research. The great number of advanced simulation applications in railroad, air and maritime transportation are excluded in this connection.

## 2.2 Traffic as a Simulation Object

Road transportation, that is, efficient movement of people and goods through physical road and street networks is a fascinating problem. Traffic systems are characterized by a number of features that make them hard to analyze, control and optimize. The systems often cover wide physical areas, the number of active participants is high, the goals and objectives of the participants are not necessarily parallel with each other or with those of the system operator (system optimum vs. user optimum), and there are many system inputs that are outside the control of the operator and the participants (the weather conditions, the number of users, etc.).

In addition, road and street transportation systems are inherently dynamic in nature, that is, the number of units in the system varies according to the time, and with a considerable amount of randomness. The great number of active participants at present at the same time in the system means a great number of simultaneous interactions. Transportation systems are typical man-machine systems, that is, the activities in the system include both human interaction (interaction between driver-vehicle-elements) and man-machine-interactions (driver interaction with the vehicle, with the traffic information and control system and with the physical road and street environment). In addition, the laws of interaction are approximate in nature; the observations and reactions of drivers are governed by human perception and not by technology based sensor and monitoring systems. In all, traffic systems are an excellent application environment for simulation based research and planning techniques, an application area where the use of analytical tools, though very important, is limited to subsystem and sub-problem level.

The reasons to use simulation in the field of traffic are the same as in all simulation; the problems in analytical solving of the question at hand, the need to test, evaluate and demonstrate a proposed course of action before implementation, to make research (to learn) and to train people.

## 2.3 Areas and Approaches in Traffic Simulation

The applications of traffic simulation programs can be classified in several ways. Some basic classifications are the division between microscopic, mesoscopic and macroscopic, and between continuous and discrete time approach. According to the problem area we can separate intersection, road section and network simulations. Special areas are traffic safety and the effects of advanced traffic information and control systems. A newly emerged area is that of demand estimation through microscopic simulation.

Recent advances in computer hardware and software technology have led to the increased use of traffic simulation models. Depending on the required objective of the simulation, models range from microscopic models, which detail the movement of individual vehicles, to macroscopic models that use gross traffic descriptors such as flow. Because of the fine level of detail required in a microscopic model, applications tend towards traffic operations over a relatively small geographical area. Macroscopic models are generally applied over a much larger, system-wide, geographical area and are more useful for transportation planning rather than traffic engineering (Roger and Sutti).

One of the oldest and most well known cases of the use of simulation in theoretical research is the car-following analysis based on the GM models. In these models a differential equation governs the movement of each vehicle in the platoon under analysis (Gerlough and Huber 1975). Car-following, like the intersection analysis, is one of the basic questions of traffic flow theory and simulation, and still under active analysis after almost 40 years from the first trials (McDonald *et al*. 1998).

The traditional simulation problem with practical orientation in road and street traffic analysis is related to questions of traffic flow, that is, to capacity and operational characteristics of facilities. Delays and queue lengths at intersections are a never-ending object of analysis and simulation studies with a newly grown international interest in roundabouts.

In the area of traffic signal control, the classic Webster's formula (Webster and Cobbe 1966) is an example of early use of simulation with practical results. In this formula a simulation-based correction is added to an analytical delay formula derived by the use of queuing theory. Modern vehicle-actuated traffic signal controllers have added a new dimension to signal control simulation. In traditional fixed time signal control only the traffic was reacting to signals, now the signals are also reacting to traffic, and the analysis of controller reactions is quite as important as the analysis of traffic itself. New solutions, like the connection of a real controller to the simulation system (Kosonen and Pursula 1991) are used in the analysis.

Most urban transportation problems are network related. In networks, one has to combine different kinds of intersections (signalized, unsignalized) and links (arterial roads, motorways, city streets). This makes the simulation quite complicated and the number of comprehensive simulation tools for network analysis is quite small in comparison to that of programs for isolated intersections and road sections. The most widely known package in this area is probably the American NETSIM from the 1970's (Byrne *et al*. 1982). Later examples of tools in this area are INTEGRATION and AIMSUN2 (Algers *et al*. 1997).

In link traffic flow analysis motorway simulation seems to be more common than simulation of ordinary two-lane two-way traffic roads. One of the reasons here is that in two-lane road environment the interactions between vehicles traveling in opposite directions have to be modeled. The platooning and overtaking are not only dependent on traffic situation but also on the road environment (sight distances, passing control). This way the problem is much more complicated than in the motorway environment. Probably the most well known programs in this area are the Swedish VTI-model (Algers *et al*. 1996) and the Australian TRARR (Hoban *et al*. 1991), both basically developed in the 1970's.

Most traffic system simulation applications today are based on the simulation of vehicle-vehicle interactions and are microscopic in nature. Traffic flow analysis is one of the few areas, where macroscopic (or continuous flow) simulation has also been in use. Most of the well known macroscopic applications in this area originate from the late 1960's or the early 1970's. The British TRANSYT-program (Byrne *et al*. 1982) is an example of macroscopic simulation of urban arterial signal control coordination and the American FREQ- and FREFLO-programs (Byrne *et al*. 1982; Payne 1971) plus the corresponding German analysis tool (Cremer 1979) are related to motorway applications. A mesoscopic approach with groups of vehicles is used in CONTRAM (Leonard *et al*. 1978), a tool for analysis of street networks with signalized and non-signalized intersections.

Traffic safety related questions have been quite a hard problem for simulation. In traditional simulation programs the drivers are programmed to avoid collisions. Thus, they do not exist. Some trials for analysis of conflict situations through simulation can be found (Karhu 1975; Sayed 1997), but a general approach to the problem and widely used safety simulation tools are still missing. Traffic safety simulation belongs to the field of human centered simulation where the perception-reaction system of drivers with all its weak points has to be described. This kind of approach is sometimes called nanosimulation in order to separate it from the traditional microscopic simulation.

On the other hand, safety aspects and human reactions in different traffic situations have for long been analyzed using driving simulation systems, where the test subjects are exposed to artificial driving tasks in a simulated vehicle and traffic environment and the driver has to react to the given traffic (Moisio 1973). Here the developments in virtual reality technology will increase the possibilities for realistic simulations (Laakko 1998; SNRA *et al*. 1998).

A new application area is the simulation of the use and effects of telematic services in traffic. This is on the other hand related to the simulation of traffic flow, and on the other hand to the simulation of human behavior and decision-making (Algers *et al*. 1997). Even the effects of totally human-free driving are tested in this area.

In recent years another new area of traffic simulation has emerged, namely simulation of travel demand. This is an area; where the analytical tradition has gone from aggregate gravity modeling to individual based disaggregate choice models. In demand simulation the question is to reproduce the trip pattern (the number, time of day, purpose, origin-destination pattern, modal split and use of routes) of the citizen population within an area by summing up the behavior of the individuals. Examples of this approach are the American SAMS and SMART, both still under development (Spear 1996). One of the most advanced modeling approaches, the American TRANSIMS, combines demand modeling and flow behavior on the streets and roads thus trying to describe the whole traffic system behavior in one simulation environment (Smith *et al*. 1995).

## 2.4 Trends in Traffic Simulation

The development in traffic simulation from the early days in the 1950's and 1960's has been tremendous. This, of course, is partly related to the development of computer technology and programming tools. On the other hand, the research in traffic and transportation engineering has also advanced during this 40-year period. Simulation is now an everyday tool for practitioners and researchers in all fields of the profession.

In the following, some of the development trends in sight are shortly discussed. Most of these trends are related to microscopic simulation. It is, however, noteworthy that there are some quite interesting new developments in the theoretical macroscopic models for fundamental traffic flow analysis, which give new insight to the fundamental speed-flow-density relationships (Helbing *et al*. 1997).

The applications are growing in size, that is, we are moving from the quite well covered local or one facility type applications to network wide systems where several types of facilities are integrated in one system. Another trend that increases the need of computing power is the more and more precise description of the physical road and street environment, especially in local applications, like in simulation of intersections. In both these cases the use of graphic user interfaces and integration to GIS and CAD systems (Etches *et al*. 1998) are a feasible approach.

The American TRANSIMS development work is an example of a network approach. The simulation of the traffic system of a whole city is based on massive use of parallel computing (Nagel and Schleicher 1994), which again is a feature that is coming more common in modern applications (Argile *et al.* 1996). Parallel computing can be achieved for example through simultaneous use of several microcomputers communicating through a local network (Argile *et al.* 1996).

In addition to the parallel computing, the modern programming principles and methods have their effect on the simulation. Object-oriented programming has been found very suitable in the description of the great amount of practically parallel interactions in traffic. Objects, or agents, can be programmed to interact in a very natural way to produce accurate models of traffic flow behavior (Kosonen 1996).

TRANSIMS is an example of still another change in the approach. The traditional traffic flow descriptions are based on continuous speed and distance variables. TRANSIMS, in turn, uses a discrete approach where the road and street network is build from elements that can accommodate only one vehicle at a time unit. In this cellular automata approach the vehicles move by "jumping" from the present element to a new one (Nagel 1996; Brilon and Wu 1998) according to rules that describe the driver behavior and maintain the basic laws of physics at present in vehicle movements.

Another way of looking at the need for system level simulations is to develop open environments where several analysis tools can be used interactively to solve the problems each one of them is most suitable. An example of this is the FHWA TRAF-program family and the FHWA Traffic Management Laboratory, whose primary goal is the development of a distributed, real-time testbed to simulate traffic conditions for Advanced Traffic Management Systems (FHWA 1994). For example, a common graphical user interface has been developed for the TRAF-family programs. The cooperation of Finnish, Swedish and British partners around the Finnish HUTSIM program for an open traffic modeling environment (Kosonen 1996) is another example of this kind of work that is going on.

In traffic flow simulation rule based approaches, like in HUTSIM and TRANSIMS, are coming more and more common. In this kind of framework the use of fuzzy logic to describe the human perception can easily be used, and there are several applications of fuzzy car-following models available (Kikuchi and Chakroborty 1992; Rekersbrink 1995; Wu *et al.*1998).

Simulation of control systems as a part of traffic operations is also coming more and more important with the wide ongoing research in transport telematics. The new control systems interact with traffic, and thus both the control system reactions and the driver reactions must be described in a true way. An especially important feature in driver reactions is the route choice decision that must be treated dynamically. In the future more and more simulation systems are embedded in control systems for the anticipation of the state of traffic flow and the effects of alternative control measures.

Virtual reality systems and programming tools become in common use, especially in simulations where the driver reactions and behavior must be analyzed in great detail.

Traffic safety related simulation will therefore probably be an area that greatly benefits from VR technology. There is, of course, no reason why VR tools could not be used in more traditional simulation tasks, as well. In planning applications VR gives new possibilities for the planning work and for the demonstration of plans to decision-makers and public (Brummer *et al*. 1998).

The combination of traditional driving simulators and traditional traffic flow simulation systems becomes possible through virtual reality techniques. In traditional driving simulator the test driver has to react to the fixed traffic that he/she sees on the display. A more natural situation is achieved if the traffic also reacts to the test driver behavior, that is, the vehicle with the test driver comes an interactive part of the simulated traffic flow.

## 2.5 Adaptation of VISSIM

Al-Ahmadi (1985) performed a study on Khobar downtown area, Saudi Arabia in his thesis dissertation entitled “evaluating policy changes using a network simulation model”. In his study he compared several available network simulation models such as SIGOP III, TRANSYT, and NETSIM and came out with a conclusion that NETSIM is a potential simulation model that can effectively be used to evaluate traffic policy changes for road networks in downtown areas.

Ratrout (1989) in his Ph.D. dissertation “Assessment of the applicability of “TRANSY-7F” optimization model to the traffic conditions in the cities of Al-Khobar and

Dammam, Saudi Arabia" reviewed all available network optimization models to select the best model for optimizing traffic in Saudi Arabia. The models that were reviewed by him are TRANSYT, SSTOP, SIGOP III, SIGRID, COMBINATION, PRIFRE, PASSER II, SOAP, PASSER III, SUB, and NETSIM. It was concluded that TRANSYT-7F model is the most appropriate model in this regard based on its ability to handle many special traffic conditions, such as more than four phases in a cycle and sign controlled intersections. This ability makes the model applicable to almost every network configuration in Saudi Arabia.

Al-Ofi (1994) conducted a study on urban intersections in Dammam and Khobar cities to investigate the effect of signal coordination on intersection safety. In his study he considered TRANSYT, SIGOP, PASSER, and MAXBAND models and found TRANSYT model as the suitable model for this study based on its attractive features over other models and it was already subjected to calibration and validation studies in several countries including Saudi Arabia (Ratrout, 1989). It was concluded that the signal coordination reduces intersection accidents and he suggested a methodology to incorporate safety into an inbuilt optimization algorithm of TRANSYT-7F model.

A traffic micro-simulation model consists of sub-models that describe human driver behavior. Important behavior models include; gap-acceptance, speed adaptation, lane-changing, ramp merging, overtakes, and car-following (Olstam and Tapani, 2004). The gap-acceptance model determines minimum acceptable distance to surrounding vehicles in the context of intersections and merging situations. Speed adaptation refers to the adaptation to the road design speed at a vehicle's current position in the network. Lane-changing models describe drivers' behavior when deciding whether to change lane or not on a multi-lane road link, e.g. when traveling on a motorway. Analogously, on two-lane rural roads the overtake model controls drivers' overtaking behavior. Finally there is the car-following model, which describes the interactions with preceding vehicles in the same lane. Most previous research on driving behavior modeling has been focused on car-following. Numerous papers have been written on this topic. However, very few qualitative comparisons and descriptions of car-following models have been made.

Previous comparisons of micro-simulation programs have been conducted by ITS University of Leeds (2000), Brockfeld *et al*. (2003) and Bloomberg *et al*. (2003). Bloomberg *et al*. (2003) used different traffic simulation programs to model and simulate a test region. The outcome of their comparison was an evaluation of the simulation programs ability to fit real traffic data from the test area. They found that none of the tested models produced better or worse results than the other. Moreover, all models generated results consistent with the methodologies used in the Highway Capacity Manual (Transportation Research Board, 1997). Brockfeld *et al*. (2003) used nonlinear optimization in order to calibrate parameters of different simulation models to traffic data from a test region. They found that the average error between simulated and real data was about 16 %. The cause behind the difference between models and measured traffic data has however not yet been fully investigated.

During 1997 and 1998, Parsons Transportation Group (PTG) conducted a study for the Long Island Rail Railroad in New York City which included a detailed evaluation of VISSIM, CORSIM, WATSIM, and TRANSIM. As a result, VISSIM was selected for that project based on its overall ability to model transit, automobile traffic, complex traffic and transit geometries, and complex user defined traffic control strategies such as preemption and priority (Brian *et al*. 2000). The VISSIM model has been validated for various real world situations and is increasingly being used by transportation professionals (Fellendorf & Vortisch, 2001)

Brian *et al* (2000) described the procedure and results of a comparison of the VISSIM simulation model to the more well known CORSIM and TRANSYT-7F models. These comparisons were made while modeling the existing traffic conditions for the roadway network surrounding the transitway mall in downtown Dallas. Based on the results of the existing conditions analysis and calibration procedure, it is concluded that both CORSIM and VISSIM were able to adequately model the existing conditions for automobile traffic within the Dallas CBD. Furthermore, the analysis and calibration procedure indicated that VISSIM could adequately model LRT operations within the transitway mall. As a result, the overall study concluded that VISSIM should be used to determine the effects of the future light rail expansion within the transitway mall.

Under ideal conditions (Fred *et al* 2002*)*, the calibration of individual components of a simulation model will improve the simulation model's ability to replicate traffic flow results that match field conditions within an acceptable range of error. Typical traffic flow characteristics that can be used in validation include traffic volumes, average travel time, average travel speed, queue lengths, and density. Unfortunately, professional guidelines that define the acceptable range of error for these characteristics have not been developed. Instead, transportation professionals have either ignored the need for validation or developed their own guidelines. Examples of validation guidelines used in recent projects by the authors and accepted by agencies such as Caltrans are contained in Table 2.1. Although these guidelines are a starting point for discussing guidelines for the transportation profession, they lack statistical justification to determine if they provide an acceptable range of error (Fred *et al* 2002).

**Table 2.1: Validation Guidelines**

| Validation Guidelines | | |
|---|---|---|
| **Parameters** | **Description** | **Validation Criteria** |
| Volume Served | Percent difference between input volume and the simulation model output or assigned volume | 95 to 105 % of observed value |
| Average Travel Time | Standard Deviation between floating car average travel times and simulated average travel time for a series of links | 1 Standard Deviation |
| Average Travel Speed | Standard Deviation between floating car average travel speed and simulated average travel speed for individual links | 1 Standard Deviation |
| Freeway Density | Percent difference between observed freeway density (from volume counts and floating car travel speed) and simulated density | 90 to 110 % of observed value |
| Average and Maximum Vehicle Queue Length | Percent difference between observed queue lengths and simulated queue lengths | 80 to 120 % of observed value |

Fred *et al* (2002) conducted a comparison of the three major traffic simulation models (CORSIM, PARAMICS, and VISSIM) in use today for a specific project involving a typical freeway interchange study and concluded that the PARAMICS and VISSIM generated simulation results that better matched field observed conditions, traffic engineering principles, and expectation/perception of reviewing agencies including California Department of Transportation (Caltrans) (Fred *et al 2002)*.

Gomes *et al* (2004) presented a procedure for constructing and calibrating a detailed model of a freeway using VISSIM and applied it to a 15-mile stretch of I-210 West in Pasadena, California. This test site provides several challenges for microscopic modeling: an HOV lane with an intermittent barrier, a heavy freeway connector, 20 metered onramps with and without HOV bypass lanes, and three interacting bottlenecks. All of these features were included in the VISSIM model. Field data used as input to the model was compiled from two separate sources: loop-detectors on the onramps and mainline (PeMS), and a manual survey of onramps and off ramps. Gaps in both sources made it necessary to use a composite data set, constructed from several typical days. FREQ was used as an intermediate tool to generate a set of OD matrices from the assembled boundary flows. The model construction procedure consists of: 1) identification of important geometric features, 2) collection and processing of traffic data, 3) analysis of the mainline data to identify recurring bottlenecks, 4) VISSIM coding, and 5) calibration based on observations from 3). A qualitative set of goals was established for the calibration. These were met with relatively few modifications to VISSIM's driver behavior parameters (CC-parameters).

Analysis of the supply and demand characteristics of the freeway lead to the conclusion that two of these bottlenecks were geometry-induced, while another was caused by weaving. A successful calibration of the VISSIM model was carried out based on this observation. As a conclusion (Gomes *et al* 2004), this study has shown that the VISSIM simulation environment is well-suited for such freeway studies involving complex interactions. With few and well reasoned modifications to its driver behavior parameters, the simulation model is capable of reproducing the field-measured response on the onramps, HOV lanes, and mixed-flow lanes.

Cate and Urbanik (2004), offers another view of truck lane restrictions on high-speed, limited access facilities. As highway volumes increase (especially those of large trucks), states across the country have sought new ways to increase driver comfort, operating efficiency, and traffic safety. More agencies are turning to the “managed lanes” concept rather than utilizing physical expansion of roadways. The managed lanes concept involves the assignment of special operating conditions to specific lanes of a roadway in order to improve the efficiency and/or safety of the roadway as a whole. This strategy typically involves restricting the use of one or more lanes on the basis of vehicle type or occupancy and may or may not vary by time of day. One such managed-lane concept utilized by many local and state agencies is truck lane-use restrictions.

While drivers of smaller vehicles are typically pleased with these lane restrictions, the previous research efforts in this area have revealed mixed results in the areas of safety and efficiency. They presented the results of an evaluation of truck lane restrictions using the VISSIM microscopic traffic simulation software package as an analysis tool. The objective of this application is to study truck lane restrictions at a very detailed level not previously available in general-purpose traffic simulation models. The suitability of VISSIM as a means of testing lane restrictions is confirmed and the necessary model adjustments are completed to determine the operational impacts of lane restrictions.

Eddie *et al* (2001) says selecting VISSIM, microscopic traffic simulation software, to model the bus deck and ramp operations at the Transbay Terminal was perhaps the most important decision made during the comprehensive analysis of the Terminal. The Transbay Terminal is an elevated terminal located in San Francisco, California, and has served as San Francisco's hub of bus transit services for over 50 years. They concluded this statement based on the following analysis.

Accurate modeling of bus operations and visual/graphical presentation of the bus operations were the primary features being evaluated during the selection process of the most appropriate traffic simulation software (Eddie *et al* 2001). Four microscopic traffic simulation software packages were considered: 1) CORSIM, 2) VISSIM, 3) Paramics, and 4) SIMTRAFFIC. SIMTRAFFIC was discarded early in their evaluation and was not considered further because it does not model bus routes. Proper modeling of bus staging operations requires the capability to code buses that pull out to the left instead of the right. Although CORSIM, VISSIM, and Paramics all model bus routes, only VISSIM models bus staging/stopping on the left-hand side of the road.

Proper modeling of bus interaction (i.e. yielding, stopping, queuing, etc.) within the Terminal was necessary to determine bus blockages and scheduling conflicts. CORSIM models bus interaction fairly well through a series of algorithms built into the software. However, VISSIM and Paramics permit the user to designate the right-of-way for conflicting movements through the use of “priority rules.” Through “priority rules,” the user can define the yielding and stopping locations on any link to accurately model the interaction between vehicles (Eddie *et al* 2001). These user defined “priority rules” make the bus interactions within the Terminal more realistic and accurate. Although the arrival of the buses to the bus stops for passenger pick-up is random the departures are based on a set schedule. All buses are set to leave the Terminal at a specific time (5:00 PM, 5:15 PM, etc.) to maintain their schedule regardless of when they arrived at the Terminal. Therefore, it was necessary to model specific departure times and not a random dwell time at the bus stop. Random dwell times at bus stops are entered for both CORSIM and Paramics. Only VISSIM permits the user to enter a specific departure time regardless of when the bus arrived at the bus stop.

Graphically, CORSIM and Paramics were not able to duplicate the smooth curves and transitions provided in the Transbay Terminal designs. CORSIM and Paramics allow some customization of curb lines; however, they primarily rely on straight lines. Proper modeling of the offsite staging/storage facility to determine bus staging/storage constraints in the facility cannot be adequately performed in CORSIM because of its limitations on link lengths and node spacing (Eddie *et al* 2001). Paramics has no limitation on node spacing; however, it will give a warning for closely spaced nodes and very short links (<25 feet) will improperly simulate vehicles along links and through nodes due to the nature of the geometry and way in which Paramics simulates. Table 2.2 summarizes the simulation software comparison as it relates to bus operations and graphics.

**Table 2.2: Simulation software comparison**

| Simulation Tool | Models Bus Routes | Left-Side Bus Stops | Accurate Bus Interaction | Bus Schedule Flexibility | Models Short Links(< 50 feet) | Import Aerials and Autocad | 3D Simulation |
|---|---|---|---|---|---|---|---|
| **CORSIM** | YES | NO | LIMITED | LIMITED | NO | NO | NO |
| **VISSIM** | YES | YES | YES | YES | YES | YES | YES |
| **Paramics** | YES | NO | YES | LIMITED | LIMITED | YES | LIMITED |
| **SIMTRAFFIC** | NO | NO | NO | NO | LIMITED | NO | NO |

Based on the above criteria (Eddie *et al* 2001), it was determined that VISSIM was the most appropriate simulation software to use for the evaluation of the Transbay Terminal alternatives. VISSIM offered excellent modeling of complicated bus routes and superior graphics.

Arroyo and Torma (2000) discussed the case study in which VISSIM software package was used. A micro-simulation model of the Old Town Transit Station was created using the VISSIM program. This transit station is in the heart of Historic San Diego. It provides public access to Old Town, a major tourist attraction sitting at the foot of one of the first Spanish settlements in California. The Old Town Transit Station includes bus access, a light-rail station and the Coaster Line (a passenger and freight rail line that connects San Diego to Los Angeles with daily service). The model is able to develop a simulation of the effects of ramp metering on local streets and the complex effect of signal timing, pedestrian volumes, train preemption, and traffic congestion. This real-time simulation can present actual Coaster, San Diego Trolley and bus line arrival and departure times in conjunction with the actual signal controller logic used for the neighboring signals.

Arroyo and Torma (2000) also discussed the case study in which VISSIM software package was used. A micro-simulation model of a proposed traffic signal near the intersection of San Marcos Boulevard and Rancho Santa Fe Road was created using the VISSIM program. San Marcos is a small city in north San Diego County. Rancho Santa Fe Road is a major north-south running arterial that intersects with San Marcos Boulevard which connects the coastal communities with the inland cities. This is a particularly congested intersection that City staff wanted to model for in depth review. The traffic signal would allow access to the Lucky's directly from San Marcos Boulevard. The city is concerned that traffic, which now queues in the two eastbound-to-northbound left turn lanes and two eastbound through lanes, requires greater storage than would be available between the proposed intersection and Rancho Santa Fe Road. Using aerial photos, field data and timing plans obtained from the City of San Marcos engineering department they were able to model conditions in the PM peak hour. Using the simulation they were able to determine feasible alternatives including the widening of San Marcos Boulevard from two lanes to three from the proposed signal to Rancho Santa Fe Road in order to increase the storage capacity. The model shows that by coordinating the timing plans for the two signals they can coexist without causing gridlock or significant increases in delay while improving circulation for Lucky's grocery store.

VISSIM has the power and flexibility that it can offer analyzing even roundabouts. HDR recently used VISSIM to analyze traffic operations for two very different roundabout projects (Trueblood M. and Dale J., 2003). The first project included the analysis of six proposed two-lane roundabouts along Missouri Avenue in St. Robert, Missouri, while the other project included the analysis of a proposed "dumbbell" arrangement along Missouri Route 367 just outside the City of St. Louis, Missouri. VISSIM was used on both projects due to its excellent graphical capabilities and its ability to model roundabouts through user-defined parameters.

Rouphail and Chae (2002) conducted a study to explore the feasibility of modeling pedestrian behavior in the context of present and proposed intersection treatment designs and operations using available computer models. Their research explored the functionality of two currently available computer models (VISSIM and Paramics). An operational roundabout scenario for low vision/blind and sighted pedestrian was constructed using measures of latency time obtained in a field setting. The effects of pedestrian gap acceptance and traffic volume were analyzed in terms of their impact on pedestrian delay and vehicle delay. These results showed that VISSIM could handle the interaction between vehicles and pedestrians or between vehicles, and could provide helpful information for any alternative intersection design or crossing arrangement under the associated traffic operation.

VS-PLUS (Fellendorf, M., 1994) is a control strategy which is currently applied in Switzerland, Austria and Germany. VS-PLUS is taken as an example for VISSIM because of some of its remarkable features:

- Runs on controllers of different manufacturers because it is a separate capsulated C-program.

- Whole flow chart of the control strategy is entered by parameter values within tables. Once the engineer has learned the complete set of parameters he can easily design and more importantly adjust existing VS-PLUS plans.

- Vehicle activation is based on vehicle streams which are controlled by signal groups (phases) instead of preset stages.

- Group of parameters is reserved for detection and priorisation of public transport vehicles (i.e. several detection points along a link including continuous comparison of present and expected arrival times by time table; rules of priority for conflicting public transport lines)

Fellendorf, M. (1994) applied VISSIM to successfully evaluate VS-PLUS. A rather complex example is chosen to present a typical application of VISSIM. Examples of this kind can be seen in most cities of Middle Europe as the priorisation programs for the public transport have been one of the major tasks in traffic engineering since the late 80´s. A 2.5 km long arterial road with seven junctions had to be signalized with some contradictory restrictions. No bus or tram should wait at a traffic light unless they stopped at a stop light in front of a traffic light anyway**.** There are tram lines which cross each other. Overall arterial co-ordination for the car-traffic should be implemented. Each vehicle stream is controlled separately. Compatible movements are not assembled to preset stages since this might reduce the flexibility of the timings. The intergreen times differ considerably. The leftmost intersection of the arterial has even 6 arms and there are two close junctions (80 m distance between) in the middle which are controlled by one controller. All this contradictory constraints of the arterial road is effectively modeled by VISSIM.

In spite of its recent market-introduction, VISSIM already has been applied for a variety of complex traffic tasks (Fellendorf, M. 1994). Some of the typical ones are:

- VISSIM calls vehicle actuated signal control strategies which are identical to the implementations in the controller. Besides testing with generated traffic flow one can test by manually initiating detectors. The triggering of the detectors is reported in macro files which can be used for running identical test situation with altered signal control parameters.

- VISSIM has been used with a variety of control systems (Fellendorf, M. 1994) like SDM, TRENDS/TRELAN, VS-PLUS and a general stage-based control strategy documented in the German guidelines. The later one works together with the traffic signed design and assessment program VISSIG.

- VISSIM has also been applied to fixed time controlled networks when the assessment of queuing was a major problem. Time-space diagrams or macroscopic programs like TRANSYT have difficulties when the staging is rather complex and times of fully compatible and semi-compatible movements overlap.

- VISSIM models all kinds of different junction layout and control like signalized and non-signalized roundabouts and junctions.

- Because of the detailed modeling of public transport VISSIM was used to evaluate different stop layouts.

- VISSIM has been used to development, evaluation and fine-tuning of transit signal priority logic.

- VISSIM has been used to evaluate and optimize (interface to Signal97/TEAPAC) traffic operations in a combined network of coordinated and actuated traffic signals.

- VISSIM has been used to evaluate the feasibility and impact of integrating light rail into urban street networks.

- VISSIM has been applied to the analysis of slow speed weaving and merging areas.

• VISSIM allows for an easy comparison of design alternatives including signalized and stop sign controlled intersections, roundabouts and grade separated interchanges.

• Capacity and operations analyses of complex station layouts for light rail and bus systems have been analyzed with VISSIM.

• Preferential treatment solutions for buses (e.g. queue jumps, curb extensions, bus only lanes) have been evaluated with VISSIM.

## 2.6 Driving in Germany

Driver parameters such as reaction time and reaction magnitude vary from driver to driver. They may also differ between different countries or territories. Drivers in, for example, Saudi Arabia may not drive in the same way as European or Asian drivers. Car-following models that is used to model traffic in different countries must therefore offer the possibility to use different parameter settings. The differences between countries may however be so big that the same car-following model cannot be used with same parameter values to describe the behavior in two countries with different traffic conditions. The VISSIM car-following model was originally designed to model driver behavior on German freeways. There is no general speed limit on German freeways, but more and more parts of the networks, especially the highly congested ones, are limited to 120 km/h. To safely facilitate heavy, high-speed traffic, special laws apply when driving on the

German Autobahn (Highway) (http://www.explorecrete.com, http://home.att.net, access on March 2005):

- In case of multi-lane roads a hierarchical set of rules is used to model lane changes. First, the driver checks whether he can improve his present situation by changing lanes. Then he checks whether he can change without generating a dangerous situation. On German freeways an additional rule forces a driver to go back to the right lane if his situation there is not worse than on his present lane. Similar special rules are implemented for trucks, where traffic regulations specify a certain lane use.
- Vehicles with a maximum speed rating of less than 60 km/h (36 mph) are prohibited as are bicycles, mopeds, and pedestrians.
- Passing on the right is prohibited: Slower vehicles must move to the right to allow faster traffic to pass, and drivers should stay in the right lane except to pass. When passing, you must do so as quickly as possible.
- Entering and exiting is permitted only at interchanges.
- During traffic jams, motorists must leave an emergency lane between the left lane and the adjacent center or right lane for emergency vehicles. This is accomplished by traffic in the left lane moving as far to the left as possible and traffic in the adjacent lane moving as far to the right as possible.
- The traffic is sometimes very heavy and also very fast especially around the big cities. Many cars are traveling at a speed of 160-200 km per hour and more and they approach from behind very fast. Check your mirrors, most important your left rear

view mirror, very carefully as far back as possible before you change into the a left lane to overtake another car. Remember always to use your blinkers when changing lane.

- The speed is controlled by radar, of course only where there is a speed limit. Much of the Autobahn has unlimited speed (note that 130 km per hour is a recommended maximum speed) and offers a fine driving experience.

# CHAPTER 3

# THE VISSIM MODEL

## 3.1 Introduction

VISSIM (Version 4.00), a German acronym for "Traffic in Towns -SIMulation", is a stochastic microscopic simulation model that has the ability to evaluate vehicular traffic, transit operations, and pedestrians. VISSIM was developed at the University of Karlsruhe, Germany during the early 1970s. Commercial distribution of VISSIM began in 1993 by PTV Transworld AG, in Germany and is distributed in the North America by Innovative Transportation Concepts. PTV VISION is the worldwide leading software suite for transportation planning and operations analyses in over 70 countries. No other software suite offers such a high level of integration within the overall transportation planning process and, in particular, between strategic planning, transport operations and traffic engineering.

The PTV vision suite integrates macroscopic analysis in VISUM with microscopic traffic simulation in VISSIM. VISUM consists of transportation information and planning system for private and public transport, graphical network editing, analysis, evaluation, assignment, forecast, environmental and other impact calculations. VISSIM consists of microscopic traffic flow simulation for traffic and transit movements. Both programs work together seamlessly, saving valuable time and reducing error. Travel demand volumes can be determined in VISUM and then exported into microscopic simulation. VISUM can also export consistent microscopic networks for VISSIM. Together, the two programs help to analyze the effectiveness of transportation scenarios including mode shift, regional route choice and operational impacts. VISUM users can incorporate the microscopic detail of VISSIM to obtain a better understanding of critical and congested parts of the network. Or, they can use VISSIM only as a graphical post-processor to produce 3D visualizations of their results. The PTV vision suite is unique in its integration of macroscopic planning and microscopic traffic analysis. It opens exciting new opportunities to planners as well as to traffic engineers to combine the strength of the two different approaches in order to produce the most accurate analysis.

Different models are integrated in one software suite to cover traffic demand, route choice, traffic flow, and pollutant emissions (see Figure 3.1). The traffic demand model follows a behavior-oriented, disaggregated approach. It computes the set of trip chains performed during one day in the analysis area. The dynamic route choice is calculated by an iterated simulation of the entire day. Each individual vehicle travels through the road network using the microscopic traffic flow model of VISSIM. Fuel consumption and exhaust gas emissions of all vehicles in the network are determined based on dynamic engine maps. In addition, the model is capable of considering additional emissions during the warm-up phase of the engine as well as evaporation emissions during parking.

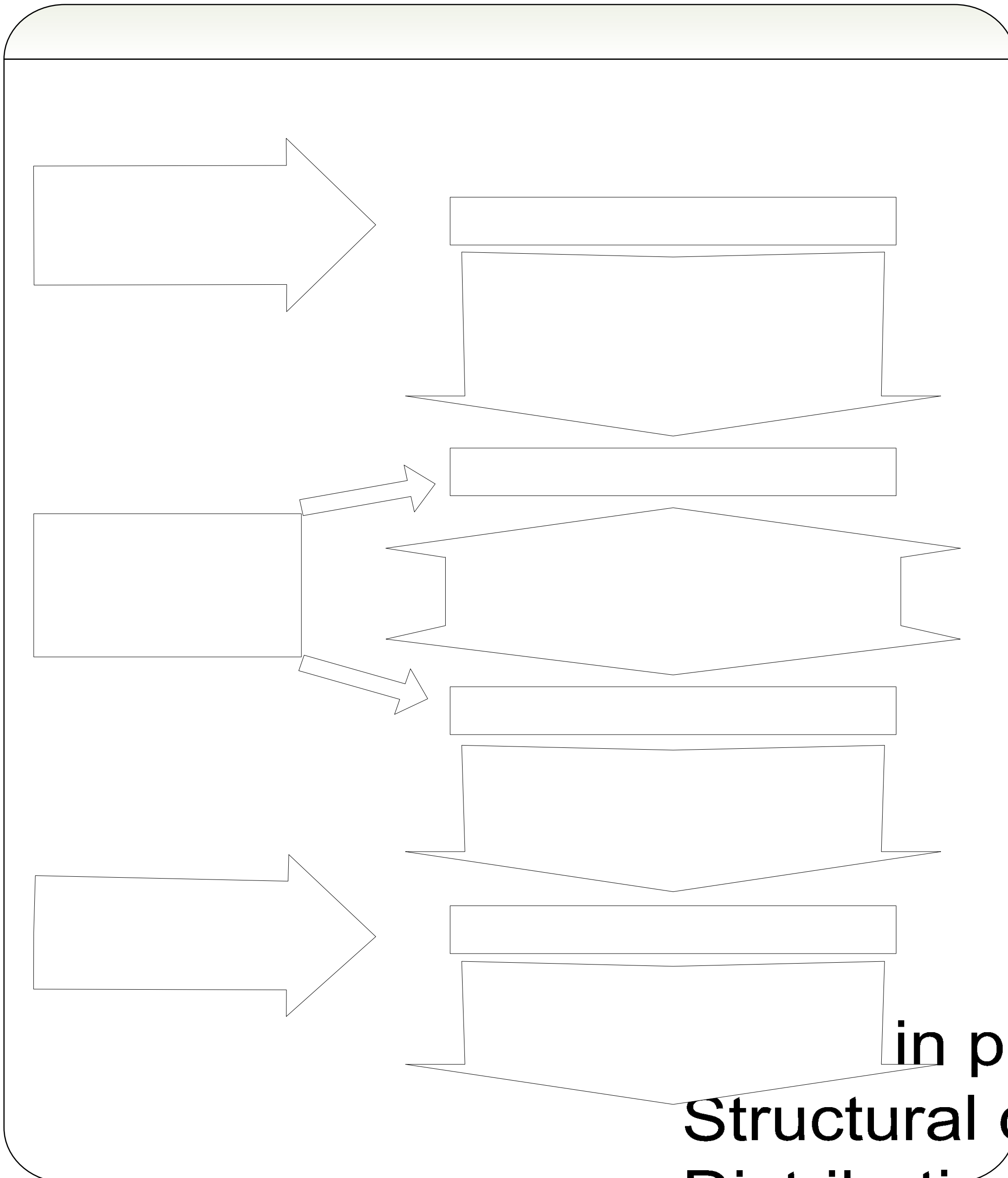


**Figure 3.1 Data flow between the individual models within the simulation software**

Typical applications of this software extend from traffic- and air quality-oriented assessment of isolated intersections up to optimizing the entire road network of cities. The completely microscopic approach across all parts of the model allows the representation of a broad variety of traffic control measures. It is state of the art to use such models separately of each other. Typically the results of one model are used as input for the next model. For example, PTV vision provides the ability to:

- Share data elements between simulation and travel demand modeling to reduce manual data entry and the potential of errors.
- Incorporate real-time traffic data into the planning and analysis phases of a project.
- Monitor and manage the transportation system through PTV vision. An abundant amount of data is collected by Traffic Management Centers. PTV vision allows this data to be presented in a way that decisions can be made.
- Share data across the internet among various transportation organizations. Depending on the level of access granted, these organizations can even query the transportation databases managed by PTV vision.
- Access GIS data from sources like ArcGIS, Mapinfo and NAVTEQ to build and update/maintain model networks for a sub-area/corridor, metropolitan region, evacuation area or even for an entire country.
- Perform intersection level of service analyses based on Highway Capacity Manual or other commonly used capacity analysis methodologies.

- Share data with signal timing optimization programs and then import optimized timings back to PTV vision. From there, the timings can be uploaded to the field and/or used to evaluate scenarios.
- Interface with the suite through COM where users can write their own scripts to automate workflow tasks.

VISSIM is capable of modeling the movements of automobiles, trucks, light and heavy rail trains, bicycles, and pedestrians on a detailed network of streets, railroads, and sidewalks. One of VISSIM's strengths is its ability to model complex traffic control strategies such as preemption and priority systems. The traffic infrastructure is modeled in detail: Number of lanes, lane markings and geometry are superimposed on scaled layout maps. Traffic regulations like priority rules, speed restrictions and signal control are simulated realistically. Since signal control is the most important measure for urban traffic management schemes various types of vehicle actuated signal control are available to extend or shorten green times depending on traffic demand. For public transport, stops are created on the road network as well as timetable information for buses and trams. Public transport priority at signalized junctions can also be modeled within the framework of traffic actuated signal control. The modeling of pedestrians is also possible, but only as far as they influence traffic signals or force vehicles to wait while they are crossing the street.

## 3.2 System Architecture of VISSIM

The simulation system consists of two separate programs (see Figure 3.2). The first program is the traffic flow model (the kernel of VISSIM), the second is the signal control model. VISSIM is the master program which sends second by second detector values to the signal control program (slave). The signal control uses the detector values to decide the current signal aspects. VISSIM receives the signal aspects and the next iteration of traffic-flow starts. The simulation is microscopic (single vehicle modeling) and stochastic with fixed time-slices (1 second intervals). The result of the simulation is an online animation of the traffic flow and offline reports of travel time and waiting time distributions.

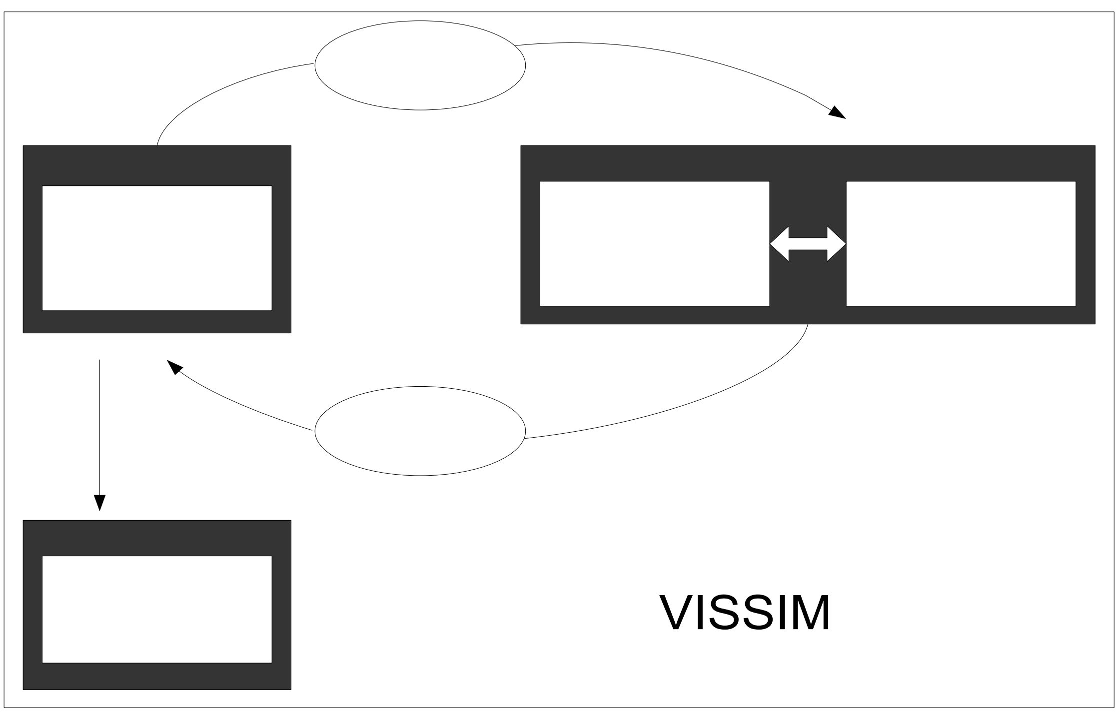


**Figure 3.2: System architecture of VISSIM**

The traffic flow model and the signal control communicate via standardized interfaces (i.e. DDE under MS Windows respectively pipes under UNIX). Flexibility is the basic advantage of splitting the two tasks into two programs. As long as the signal control strategy is available as a C-program it can be implemented in VISSIM. Even if the signal control is only available on the controller as Assembler code, the whole controller can be joined with VISSIM. A hardware solution via serial RS-232 ports is then required.

## 3.3 The Traffic Flow Model

The quality of a traffic simulation system depends highly on the quality of the traffic flow model at its core. The car-following and the lane-changing model are part of this kernel. The car-following model (also called spacing-model) describes the movement of a vehicle whose driver wants to drive faster than the present speed of the preceding vehicle. If more than one lane is available vehicles tend to overtake which is modeled in the lane-changing algorithm.

The traffic flow model in VISSIM is a discrete, stochastic, time-step based microscopic model with driver-vehicle-units as single entities. The model contains a psycho-physical car following model and a rule-based algorithm for lateral movements. The model is based on the continued work of Wiedemann (1974). The basic idea of the Wiedemann model is the assumption that a driver can be in one of four driving modes (see Figure 3.3):

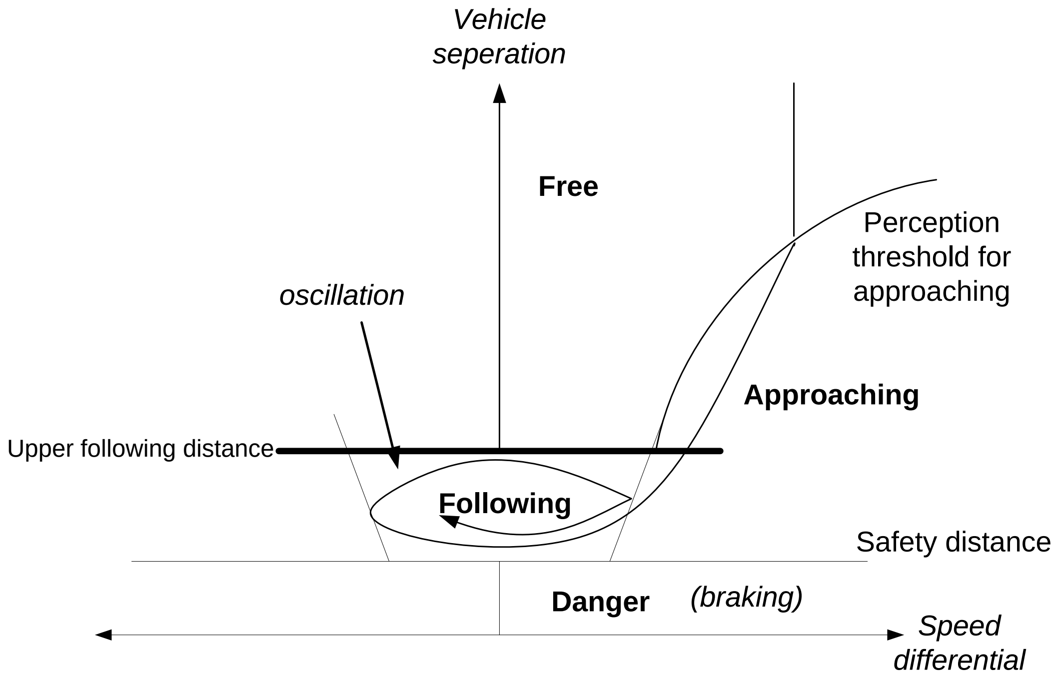


**Figure 3.3: Car-following model by WIEDEMANN**

***Free driving*** is the mode in which the vehicle is not influenced by preceding vehicles. In this mode the driver seeks to reach and maintain his individually desired speed. In reality, the free driving speed cannot be held constant. Rather, it oscillates around the desired speed due to imperfect throttle control.

***Approaching*** is the mode in which a vehicle goes through the process of adapting his speed to the lower speed of a preceding vehicle. While approaching, a driver applies deceleration so that the speed differential of the two vehicles is zero in the moment he reaches his desired safety distance.

***Following*** is the mode in which a driver follows a preceding car without any conscious acceleration or deceleration. He keeps the safety distance more or less constant, but again due to imperfect throttle control and imperfect estimation, the speed difference oscillates around zero.

***Braking*** is the mode in which the driver applies medium to high deceleration rates when the distance falls below the desired safety distance. This can happen if the preceding car changes speed abruptly, of if a third car changes lanes in front of the observed driver.

For each mode, the acceleration is described as a result of speed, speed difference, distance and the individual driver and vehicle characteristics. The driver switches from one mode to another as soon as he/she reaches a certain threshold that can be expressed as a combination of speed difference and distance. The ability to perceive speed differences and to estimate distances varies among the driving population, as well as the desired speeds and safety distances. Because of the combination of psychological aspects and physiological restrictions of the driver's perception, the model is referred to as a psycho-physical car-following model.

As stated above, vehicle speeds play an important role within the traffic flow model of VISSIM. Desired speeds within VISSIM are coded in three separate manners. The first is when vehicles enter the network. Each vehicle is assigned its own unique speed within a range based on an *empirical curve* defined by the user. The empirical curve can be defined to match field data (e.g., S-curves from speed studies) or assumptions can be used such as the posted speed limit. Vehicles oscillate around their desired speed until traffic conditions, speed zones, or roadway geometry requires them to change speeds. Speed zones are coded using *desired speed decisions*. Vehicles will not change speeds until they pass over the desired speed decision line. To capture the influence of roadway geometry (e.g., curves are intersection turning movements) on speeds, VISSIM uses *reduced speed areas*. The user defines the area where vehicles need to reduce speeds and then assigns a speed distribution to that area. Vehicles begin to decelerate for the reduced speed area in advance of reaching it. This behavior is similar to a motorist desiring to make a right turn who begins to decelerate before arriving at the point where he needs to turn. After passing over the reduced speed area vehicles begin to accelerate back to their previous desired speed. All speed distributions used in VISSIM can be vehicle-type-dependent. For example, the user may use slower turning speeds for trucks as opposed to cars.

The difficulty of such a psycho-physical model starts with the random distribution of the thresholds. Continuous measurements of different traffic conditions on highways and urban streets are required to model the traffic in a realistic way, which is done at the University of Karlsruhe.

Complex set of rules are required to model the lane-changing behavior which depends very much on the type of street. In Europe for example legally the near-side-lane on motorways has to be used as long as possible. On urban roads this rule is not valid since the next turning direction is one of the most important parameters for the decision on the choice of the present lane. If a faster DVE approaches a slower one on the same lane it checks if it could improve its position by changing to a neighboring lane. Doing so it respects up to six other vehicles at each second (see Figure 3.4).

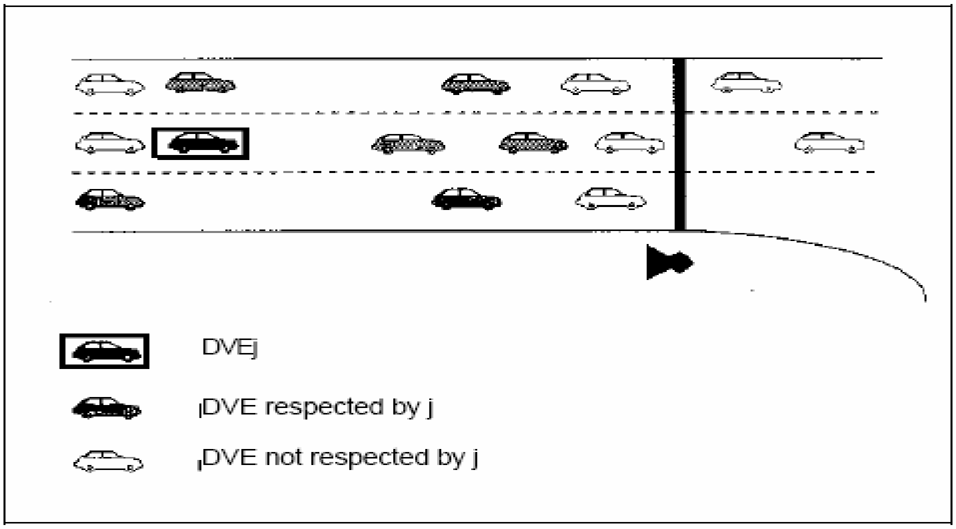


**Figure 3.4: Each vehicle regards unto six neighboring vehicles**

Each DVE can be characterized by a set of parameters describing the above mentioned traffic flow model. The values are randomly chosen out of user-defined distributions. The most important parameters of a DVE are classified into three groups as follows:

1. Technical description of a vehicle

- vehicle length and type (car, truck, bus, tram, pedestrian)
- maximum speed
- maximum acceleration and deceleration as a function of speed
- present position within the network
- present vehicle speed and acceleration

2. Behavior of a DVE

- desired speed of the driver
- perceptual threshold of the driver (ability to estimate differences in spacing and speed, desire of safety and perception of risk)
- acceleration as a function of present speed and desired speed of the driver

3. Interaction between several DVE´s

- Pointers to the DVE´s direct in front and rear on the same and the neighboring lanes
- Pointers to the present link and the next intersection
- Pointers to the next traffic light

In order for VISSIM to model complex traffic control strategies such as preemption and priority systems, a vehicle actuated program (VAP) must be developed in most cases. This is essentially a computer program, written in a language similar to BASIC that is used to emulate a traffic signal controller or other types of traffic control devices such as gate crossings and LRT track switches. In addition to the VAPs, there are existing controller software packages that can work directly with VISSIM. Some of these packages are capable of SCATS and SCOOT operations in addition to built-in preemption and priority systems.

## 3.4 Network of Streets and Lines

The basic element of the street network is a one or multilane link. The network is composed of links and its connectors. Links are used to build the major roadway segments. When the number of lanes change, a new link is required. A number of attributes can also be assigned to links including driver behavior (car-following and lane-changing), number of lanes, lane widths, lane restrictions and gradient. Because VISSIM does not use the traditional link and node approach, a link within VISSIM can have several internal inflection points without affecting how the model simulates traffic flow through the link.

Connectors are used to connect links. They are the primary feature used to create an intersection and control the path of vehicles through the intersection. Connectors can be thought of as “ramps” onto links. An important consequence of this is that as vehicles travel onto a connector, it is possible that a vehicle on a link (possibly coded underneath the connector) may not recognize that there is a conflicting vehicle on the connector. This can lead to what looks like collisions when viewing the simulation, but rather vehicles are really going under or over each other in the model’s universe. Most of the other connector features are very similar to links with the exception of their influence on lane-changing behavior. The user can specify a lane-change look-back distance from the connector and an emergency stop distance. The lane-change distance defines the distance at which vehicles will begin to attempt to change lanes. The emergency stop distance defines the last possible position for a vehicle to change lanes. A connector can be placed on any position of a link. It can be valid for all vehicles, certain types (i.e. buses) or a set of vehicles (i.e. only right turning vehicles). Cross sections for turning decisions have to be placed. They become valid at the next possibility.

Signal control is modeled by placing the signal heads at the positions of the stop lines. The signal aspects are part of the underlying signal control strategy. Detectors measure the traffic for the signal control (i.e. gap, occupancy, presence) and they are used for microscopic and macroscopic measurements (i.e. speeds, volumes, and travel times). The desired speed in urban areas does not derive directly from the technical data of a car but rather from the geometrical layout of the street and its junctions. Usually the desired speed is reduced around junctions. Semi-compatible movements are modeled via gap acceptance. The values of gap acceptance and waiting positions are user-definable. A public transport route is defined as a sequence of stops along lines. The stops are either on the link or next to it.

One of the most powerful features within VISSIM is the coding of routing decisions. Routing decisions allow the user to “route” traffic through an intersection by movement and, if needed by lane. Routes can extend through one intersection or an unlimited number of intersections. Routing decisions consist of a routing decision point and any number of destination points. The user defines the volume on each route as either a percentage of the total volume passing the routing decision point or the actual volume on each route.

Within VISSIM, acceptable gaps that drivers take are controlled by “priority rules”. The coding of “priority rules” within VISSIM provides great flexibility that allows traffic flow within a roundabout to be simulated closely to what might be expected in the real world. A priority rule consists of one stop line and one or more conflict markers that are associated with the stop line. Depending on the current conditions at the conflict marker(s), the stop line controls whether vehicles can cross the stop line or not. Two conditions need to be satisfied before a vehicle can cross a stop line: minimum headway (distance) and minimum gap time.

## 3.5 Vehicle Arrivals

For every vehicle arriving at the entry points of the network, VISSIM has to generate the arrival time. The volumes at the entry points are user-definable. The arrival profile is entered as 5 or 15 minute interval values. Within one time interval VISSIM assumes a POISSON arrival distribution. The following data can be entered:

- entry points
- vehicle composition (car, trucks) of the streams
- distribution of arrivals over time
- time-table for bus and tram
- bus and tram routes

## 3.6 Input Data Required for VISSIM

***Network Geometry:*** Network plan showing whole study area, link type (e.g. urban, interurban, footpath, etc.,), and number of lanes in link, lane widths, link gradient, and link connectors for turning movements.

***Traffic Flow Data:*** Input flows for each entry link and turning movements for each junction, vehicle mix, vehicle lengths, desired speeds (actual speed of a vehicle at free flow) at all entries of the study area and for all speed changes with in the study area.

***Signal Control Data:*** For every signalized junction cycle length, amber and red-amber times and timings for red end and green end for each signal phase are required.

## 3.7 Output Characteristics

VISSIM offers a wide range of evaluations that result in data being displayed during a simulation/test run and/or in data being stored in text files. As the text files use semicolons and delimiters they can easily be imported in spreadsheet applications (like Microsoft Excel) in order to use them for further calculations or graphical representation. VISSIM is capable of producing output that contains measures of effectiveness commonly used in the traffic engineering profession. These measures of effectiveness include travel time, average link speed, total delay, stopped-time delay, stops, queue lengths, fuel emissions, fuel consumption, etc,. One advantage VISSIM has is that it can produce very detailed results on any time interval defined by the user. This is a common need in research applications or when developing new control algorithms.

## 3.8 Typical Applications of VISSIM

VISSIM can be applied to model a variety of operations including the following:

- Model the development, evaluation, and fine-tuning of transit signal priority logic.
- Model various types of signal control logic.
- Model, evaluate or optimize traffic operations in a combined network of coordinated and actuated traffic signals.
- Model and evaluate the feasibility and impact of integrating light rail into urban street networks.
- Model weaving and merging areas.
- Model design alternatives including signalized and stop sign controlled intersections, roundabouts, and grade separated interchanges.
- Model capacity and operations analyses of complex station layouts for light rail and bus systems.
- Model preferential treatment solutions for buses (e.g. queue jumps, curb extensions, bus-only lanes).
- Model ramp metering

- Model traffic calming measures, pedestrian and cyclists
- Model and evaluate lane restrictions (HOV lane, trucks).
- Comparison of junctions with regard of design alternatives (roundabouts, un-signalized and signal controlled; grade separated interchanges)
- Design, test and evaluation of vehicle-actuated signal control operations
- Capacity analysis and testing of transit priority schemes
- Feasibility analysis of large networks (e.g., motorways) with alternative route choice using dynamic assignment
- Impact analysis of Intelligent Transport Systems (ITS), e.g., variable message sign systems, ramp metering, incident diversion, special lanes, route guidance systems
- Wide range of highly specialized traffic engineering tasks, such as capacity analysis of railroad block section operation and of toll plaza or border control facilities.
- Besides the modeling of larger networks also more local studies can be performed, e.g. a comparison of two signal control methods for a complex junction. For studies of this kind, the model of traffic demand is not used. Instead, the user provides an origin-destination-matrix for the modeled network to the traffic flow model.
- Due to the microscopic modeling of traffic flow the impacts of traffic control measures can be analyzed on a very detailed level.

## 3.9 Advantages of VISSIM over other widely used models

- VISSIM is more capable of modeling the interaction of various modes of transit with automobile traffic. VISSIM can model light rail transit and can model more bus routes and bus stops than other models. In addition, VISSIM is capable of modeling gates at rail crossings as well as complex traffic control strategies such as preemption and priority systems.
- VISSIM network editing is done completely through the use of its Graphical User Interface which runs in various versions of Microsoft Windows. Due to the fact that the interface used to build a VISSIM model is also the same interface used to view the animation, you know exactly what your network structure is going to look like as you are building your model. In addition, VISSIM can also import scaled versions of background bitmap files which can be used to build the model upon.
- VISSIM uses links and connectors. These links and connectors are used to construct both streets and intersections. This permits VISSIM to be very flexible when working with complex geometries. VISSIM can easily be used to accurately model curvature, variable location of stop lines, and correct turning paths.
- VISSIM's output is contained in several separate output files. VISSIM can produce very detailed results on any time interval defined by the user. This is a

common need in research applications or when developing new control algorithms.

- VISSIM provides animation capabilities with major enhancements in the 3-D simulation of vehicle types (i.e. from different passenger cars, trucks, transit vehicles, light rail and heavy rail). In addition, movie clips can be recorded within the program, with the ability to dynamically change views and perspectives. Other visual elements, such as trees, building, transit amenities and traffic signs, can be inserted into the 3-D animation.
- VISSIM provides a flexible platform with several user-definable features that allow the user to more realistically model the traffic operations of roundabouts. Unlike the modeling of four-way stop-controlled or signalized intersections, roundabouts are based more on the ability of drivers to accept or deny gaps.
- VISSIM has the ability to control gaps and headways on a lane-by-lane basis to more accurately simulate these types of operations present at roundabouts.
- Another benefit that VISSIM incorporates is that roadway networks consist of a link-connector structure instead of a link-node structure. This enables VISSIM to simulate short links without affecting the behavior of drivers as they proceed through small links. With VISSIM it is possible to model any kind of intersection (or sequence/network of intersections) with a precision down to one millimeter!

## 3.10 Disadvantages of VISSIM

- In-depth knowledge of traffic engineering techniques required.
- High learning curve due to depth of software features.
- High cost of software.
- VISSIM is complex and requires extensive knowledge of the program and its features.
- The models used within VISSIM must be created with care, for minor inconsistencies between the model and the facility's design can result in major errors in the analysis.
- Due to the number of variables within the VISSIM software, there are many opportunities for adjustment within the model (such as driver and vehicle characteristics, gap acceptance, yield characteristics, and speed change characteristics).

## 3.11 System Requirements

As a 32-bit application VISSIM runs under Windows 95/98/2000/ME/NT 4.0 (or later). The performance of a VISSIM simulation is mainly dependent on the number of vehicles simultaneously contained in the network and on the number and type of signal controlled junctions included. Thus using identical VISSIM input files, a faster computer will always lead to a faster simulation. For very large applications (like a network of at least half a city with more than 50 signal controlled junctions) at least one GB of RAM is recommended.

To provide an optimal desktop layout when multiple windows are displayed simultaneously it is beneficial to use the highest resolution supported by the hardware configuration. At a minimum, a resolution of 1024 x 768 pixels should be used. In order to increase 3D animation speed it may be useful to reduce the screen resolution temporarily. For 3D animation of a simulation VISSIM uses Open-GL™ routines. Thus a graphics adapter with Open-GL™-support takes a lot of the workload and significantly increases animation speed. Graphics adapters with Nvidia chipsets are recommended.

It is strongly recommended that the latest driver update of your graphics adapter be used since simply updating the driver can solve most problems that occur with the 3D animation. For most graphics adapters a driver update can be obtained via download from the Internet.

# CHAPTER 4

# RESEARCH METHODOLOGY

## 4.1 Introduction

The methodology process that employed in this study commences with the adaptation of the VISSIM model and calibrating it for the existing traffic conditions until its validation is reached. In this process, as displayed below the flow chart of research methodology in Figure 4.1 the very first step is to select a suitable site, a site that does not cause any difficulty in data collection and model formulation. The next task in this study is to collect the required input data for the VISSIM model and to collect the calibration data to compare with simulated results from the field. Then the study progress by performing the task of network coding, simulating and verifying the coded network and determining the required number of simulation runs. Then the very important task of this study, model calibration is considered.

Calibration is the process by which the individual components of a simulation model are refined and adjusted so that the simulation model accurately represents field-measured and observed traffic conditions. At last going on to final stage, validation of the modified model by implementing the adjusted parameters on another network and comparing the field observed measures of effectiveness and simulated results.

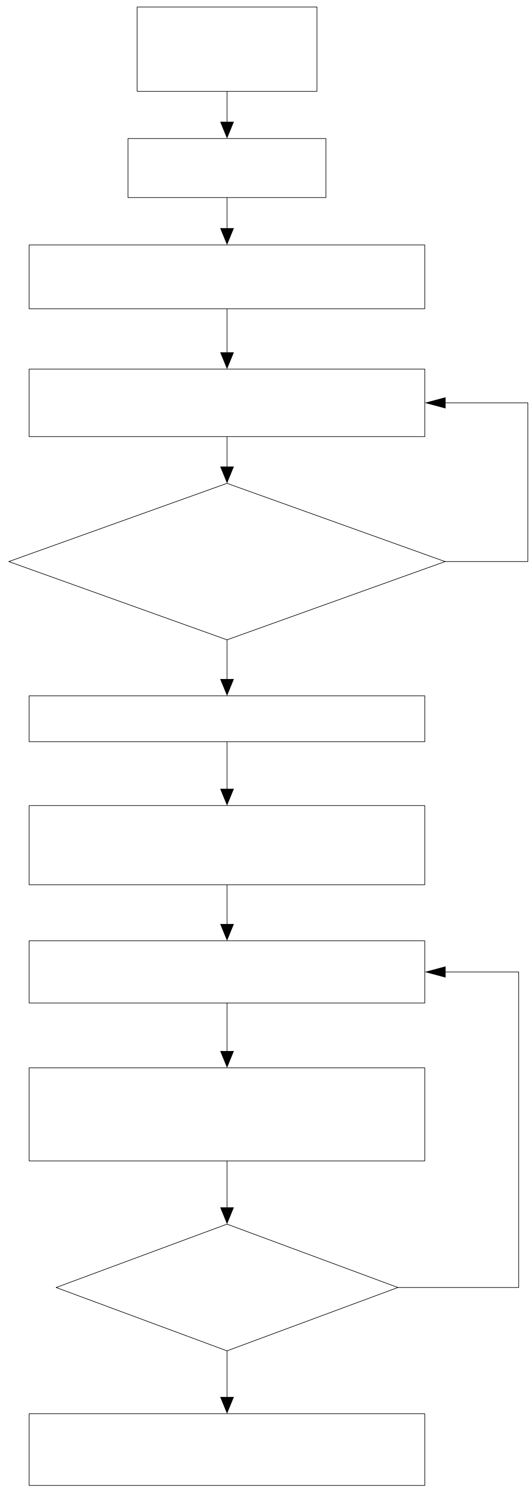

**Figure 4.1: Flow Chart of Research Methodology**

## 4.2 Adaptation of the VISSIM Model

Simulation is basically a dynamic representation of some part of the real world achieved by building a computer model and moving it through time. The results obtained from any simulation model will be as good as the model replicates the specific real world characteristics of interest to the analyst. The successful utilization of the model depends on selecting the proper values of the parameters that describe the traffic performance and driving behavior characteristics.

Most of the default values used in the original traffic simulation model VISSIM reflect the driving performance and traffic conditions as observed in Germany, where the software originated. These values are expected to be different for the local traffic conditions of Saudi Arabia. Therefore to facilitate the application of the VISSIM model to the local traffic conditions calibration and/or modification of the default values of the model are considered.

## 4.3 Site Selection

Selecting a suitable network site, a site that satisfy the study requirement and which does not cause any complexity in data collection and model formulation for study was not an easy task. Though VISSIM model can simulate any type of network and can simulate a network with even different cycle lengths it is recommended to choose a network site with same cycle lengths or a multiple of common cycle length to avoid any form of discrepancy in collecting measures of effectiveness from the field, especially for queue length and travel time.

To comply with these limitations, city map of Khobar and Dammam were studied and checked the cycle lengths of the major signalized arterial from the field. Two arterials each from Khobar and Dammam were found satisfying the criterion of a common cycle length. Khobar arterial is a Dhahran Street section as shown in a Figure 4.2 consisted of three signalized intersections connecting Makkah Street, Prince Hamoud Street and King Abdul Aziz Street. This Dhahran Street was considered for the study of model calibration. It consists of four lanes in each direction, and it is located in mixed residential and commercial area. Dammam arterial is a 1$^{st}$ Street section located amidst the center of the city as shown in Figure 4.3. It was used for the study of model validation. It is consisted of three signalized intersections connecting King Khaled Street, King Saud Street and King Abdul Aziz Street. It contains three lanes in each direction and it is also located in a mixed residential and commercial area.

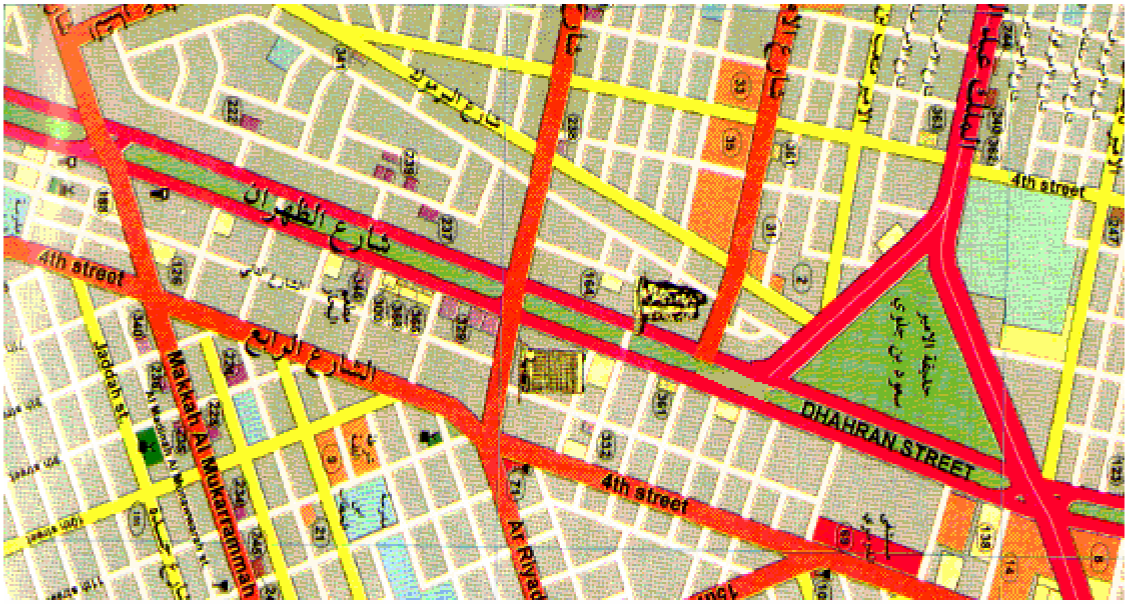


**Figure 4.2: Arterial for Model Calibration (Dhahran Street, Khobar)**

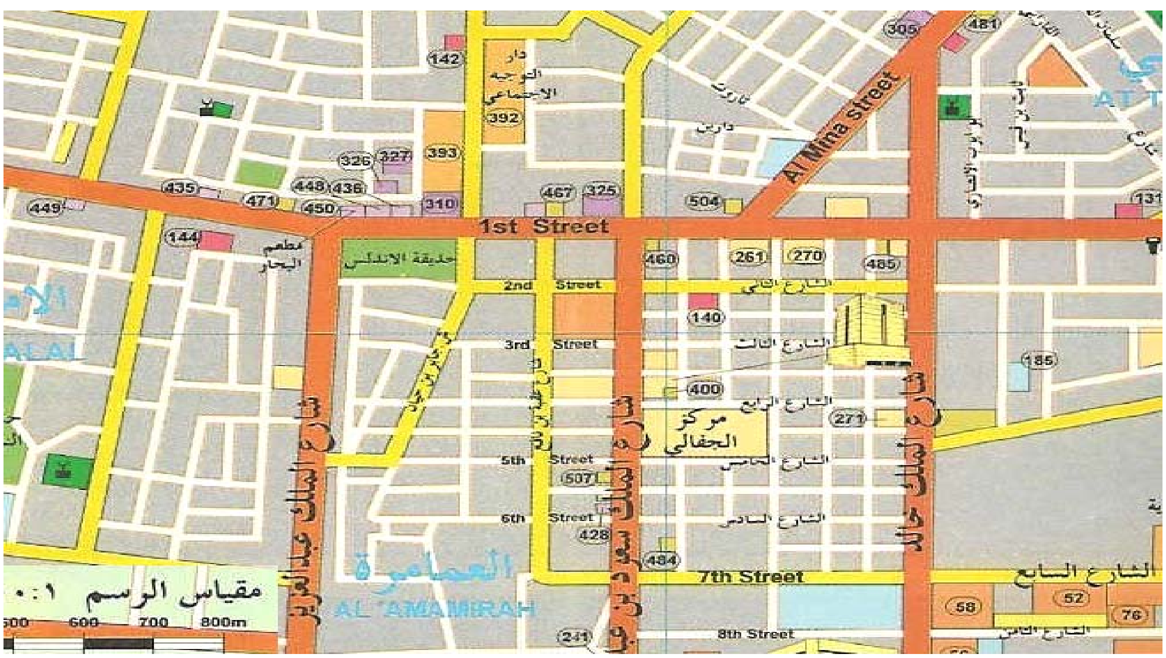


**Figure 4.3: Arterial for Model Validation (1st Street, Dammam)**

## 4.4 Data Collection

The phase of data collection was a most important task in this study and at the same time it was the most hard-hitting job in the entire study. Microscopic simulation model VISSIM have complicated data input requirement and have many model parameters. To build a VISSIM simulation model for this network and to calibrate it for the local traffic conditions, two types of data are required. The first type is the basic input data used for network coding of the simulation model. The second type is the observation data employed for the calibration of simulation model parameters.

*Basic Input Data*: Basic input data include data of network geometry, traffic volume data, turning movements, vehicle characteristics, travel demands, vehicle mix, stop signs, traffic control systems, etc.

*Data for Model Calibration*: The coded VISSIM simulation network needs to be further calibrated to replicate the local traffic conditions. The calibration involves comparing the simulation results against field observed data and adjusting model parameters until the model results fall within an acceptable range of convergence. Data collected for model calibration includes traffic volume data, travel time, maximum queue length, average queue length and average link speed. In collecting all types of data standard procedure were followed. A summary of data collected for both the networks for this study is shown below in Table 4.1.

**Table 4.1: A summary of data collected**

| Major Category | Data Type |
|---|---|
| Network Data | 1. Links with start and end points.<br>2. Link lengths.<br>3. Number of lanes.<br>4. Lane drops and lane gains.<br>5. Lane storage length for turning movements.<br>6. Connectors between links to model turning movements.<br>7. Position of signal heads/stop lines. |
| Traffic Volume Data | 1. Through and turning traffic volume counts.<br>2. Vehicle composition.<br>3. Vehicle length. * |
| Vehicle and Driver Performance Characteristics Data | 1. Saturation flow.<br>2. Average vehicle spacing.<br>3. Vehicle acceleration and deceleration. * |
| Speed Data | 1. Desired speed.<br>2. Right turning and left turning movements speed. |
| Signal Control Data | 1. Cycle length.<br>2. Offsets.<br>3. Phase direction.<br>4. Phase duration.<br>5. Priority rules. |
| Data for Calibration | 1. Section travel time.<br>2. Average link speed.<br>3. Average queue length.<br>4. Maximum queue length. |

*Default values were used

### 4.4.1 Traffic Volume Study

Traffic volume is defined as the number of vehicles passing a point on a highway or lane during a specified period. It is the most basic of all parameters and the one most often used in planning, design and control, operation and management analyses. Since, volume is the most basic of all parameters and is the basis for traffic planning, the observation and analysis of traffic volumes were done with the utmost care and accuracy. Inaccurate volume information will compromise the accuracy and effectiveness of all analyses and improvements developed from it.

For a variety of reasons, most traffic counts are conducted manually. A principal reason is time; studies conducted for duration of less than 8 to 10 hours do not justify the effort required to set up automated counting equipment, unless such equipment is already permanently installed at the site. A second reason is that certain types of information such as turning movements, pedestrian counts are more easily and accurately obtained using manual techniques. Manual counts may be quickly planned, require little equipment, and are relatively cheap; except for the labor cost of those conducting the study. Therefore manual counting was opted.

Traffic volumes were collected manually for a period of one hour from 3:45 pm to 4:45 pm at each intersection for both the networks. All the intersections in the networks have four approaches except one intersection at Dammam site which has only three approaches. At each approach one trained person was placed to collect traffic volume coming from that approach. Volume data obtained from the field for both the networks are provided in Appendix A.

### 4.4.2 Speed Study

Speed is the most important parameter describing the state of a given traffic stream. Speed is defined as the rate of motion, in distance per unit of time. In a moving traffic stream, each vehicle travels at a different speed. Thus, the traffic stream does not have a single characteristic speed but rather a distribution of individual vehicle speeds. From a distribution of discrete vehicle speeds, a number of average or typical values may be used to characterize the traffic stream as a whole. Average or mean speeds can be computed in two different ways, Time mean speed (TMS) and Space mean speed (SMS), yielding two different values with differing physical significance. Time mean speed (TMS) is defined as the average speed of all vehicles passing a point on a highway over some specified time period. Space mean speed (SMS) is defined as the average speed of all vehicles occupying a given section of highway over some specified time period.

In essence, time mean speed is a point measure or spot speed, while space mean speed is a measure relating to a length of lane. Both types of speeds were collected from the field. One as desired speed of vehicles required supplying in VISSIM as an input and the other one as average link speed required for the calibration of the model.

#### 4.4.2.1 Desired Speed

For any vehicle type the speed distribution is an important parameter that has a significant influence on roadway capacity and achievable travel speeds. If not hindered by other vehicles, a driver will travel at his desired speed (with a small stochastic variation called oscillation). If overtaking is possible, any vehicle with a higher desired speed than its current travel speed is checking for the opportunity to pass without endangering other vehicles. The intent of desired speed study is to determine the speeds that drivers select when unencumbered by traffic congestion. Thus, such studies are taken for vehicle type CAR under conditions of free flow (light traffic) within the network.

Speed data are collected by using direct measurements of speed of individual vehicle using the Doppler principle (i.e., radar). Speed measurements are taken upstream on the approach just before the point the traffic begins to decelerate from a possible stop at the intersection. Since radar device is currently the principal means for direct speed measurement, it is used for directly observing the speed of the vehicles passing a fixed point on the road. With in the network on either direction of the road two spots, where the free flow conditions prevailed, are selected for the desired speed study. Data was collected during the same period 3:45 pm to 4:45 pm in which volume counts were taken. A radar gun was easily operated by a single person. Operators randomly targeted the vehicles and recorded the digital readings displayed on the unit. Since VISSIM allows providing a range of speed distribution, from this data a range of speed distribution containing greatest number of speed observations were determined and found to be 58 kmph to 68 kmph for Dhahran Street in Khobar and 48 kmph to 58 kmph for 1$^{st}$ Street in Dammam.

### 4.4.2.2 Average Link Speed

Average link speed is required to collect from the field as a measure of effectiveness to compare it with the VISSIM output. To determine the average link speed, a segment on the link is marked and speed data are collected by running a test car over this section of link and the amount of time taken to traverse this section of link during the specified hour 3:45pm to 4:45 pm was recorded. Six runs are conducted for each link to determine the average speed of that link. The driver of the test vehicle proceeds along the study route in accordance with the average car technique. In this technique test vehicle travels according to the driver's judgment of the average speed of the traffic stream. Each run results in a space mean speed or average link speed estimated by dividing the runs' travel time in to the section length and its average gives the average link speed. Table 4.2 and Table 4.3 shows the field observed average link speed for Dhahran Street and Dammam 1st Street respectively.

## 4.4.3 Travel Time

Travel time is defined as the total time for a vehicle to complete a designated trip, over a section of street or highway or from a specified origin to a specified destination. Travel time study can be conducted using the average vehicle, moving vehicle, license plate, direct observation, or interview method. The first two methods require test vehicles, while the other methods do not. The choice of method depends on the purpose of study; the type of roadway segment under study; the length of the segment; the time of day of interest; and the personnel, equipment, and resources available. The first two are the most commonly used methods and average car method has shown excellent correlation with actual travel times (Douglas *et al*. 1994).

Test-car runs are done by using average car technique, in which test vehicle travels according to the driver's judgment of the average speed of the traffic stream. The average vehicle method measures travel time and distance traveled on the study route. This method requires a test car, a driver and observer/recorder, two stop watches, and data collection forms. The distances between control points and the length of the total route were obtained from the vehicle odometer. Test runs are began promptly at the beginning

**Table 4.2: Average Link Speed for Dhahran Street**

| **S. No.** | **Link** | **Field Average Link Speed Km/h** |
|---|---|---|
| 1 | Makkah Street Intersection to Hamoud Street Intersection | 46.2 |
| 2 | Hamoud Street Intersection to Abdul Aziz Street Intersection | 52.15 |
| 3 | Abdul Aziz Street Intersection to Hamoud Street Intersection | 50.15 |
| 4 | Hamoud Street Intersection to Makkah Street Intersection | 57.45 |

**Table 4.3: Average Link Speed for Dammam 1st Street**

| S No | Link | Field Average Link Speed Km/h |
|---|---|---|
| 1 | King Khaled Street Intersection to King Saud Street Intersection | 32 |
| 2 | King Saud Street Intersection to King Abdul Aziz Street Intersection | 39 |
| 3 | King Abdul Aziz Street Intersection to King Saud Street Intersection | 33 |
| 4 | King Saud Street Intersection to King Khaled Street Intersection | 29 |

of the study period that is at 3:45 pm to 4:45 pm so as to complete the required sample of runs before conditions along the route change. The observer recorded time readings from the stop watch as soon as the vehicle passes the first point of the study segment. As the test vehicle passes the end point of the study segment, the observer read the stop watch and noted the total time of the run. This procedure was repeated until the six required number of sample runs were reached and the average of these runs was taken to get the average travel time for that study segment. A summary of field observed average travel time for study segments for both the networks are presented below in the Table 4.4 and Table 4.5.

**Table 4.4: Average Travel Time for Dhahran Street**

| S.No. | Segment | Distance (m) | Field Average Travel Time (s) |
|---|---|---|---|
| 1 | Makkah Street Intersection to Hamoud Street Intersection | 735 | 59 |
| 2 | Hamoud Street Intersection to Abdul Aziz Street Intersection | 985 | 68 |
| 3 | Abdul Aziz Street Intersection to Hamoud Street Intersection | 1000 | 73 |
| 4 | Hamoud Street Intersection to Makkah Street Intersection | 750 | 55 |
| 5 | Makkah Street Intersection to Abdul Aziz Street Intersection | 1873.5 | 188 |
| 6 | Abdul Aziz Street Intersection to Makkah Street Intersection | 1898.2 | 168 |

**Table 4.5: Average Travel Time for Dammam 1st Street**

| S No | Segment | Distance | Field Average Travel Time (s) |
|---|---|---|---|
| 1 | King Khaled Street Intersection to King Saud Street Intersection | 330.0 m | 34 |
| 2 | King Saud Street Intersection to King Abdul Aziz Street Intersection | 350.0 m | 32 |
| 3 | King Abdul Aziz Street Intersection to King Saud Street Intersection | 350.0 m | 42 |
| 4 | King Saud Street Intersection to King Khaled Street Intersection | 320.0 m | 47 |
| 5 | King Khaled Street Intersection to King Abdul Aziz Street Intersection | 761.4 m | 91 |
| 6 | King Abdul Aziz Street Intersection to King Khaled Street Intersection | 759.2 m | 108 |

## 4.4.4 Queue Length

Queue length studies have several important applications. Queue length data can help determine the length of storage lane needed or can provide a useful measure of traffic signal efficiency. In this study queue length is determined from the field at each intersection as a measure of effectiveness to compare with the VISSIM model output. Observers count the number of vehicles in a standing or slowly moving queue at designated time intervals. At each intersection of both the networks one observer was placed to record the queue length of major approaches. At intersections observers were instructed to record the queue length at the start of the green interval and the end of the yellow interval. This study was conducted during the specified period of study i.e., 3:45 pm to 4:45 pm. A summary of field observed average and maximum queue lengths for major approaches for both the networks are presented below in the Table 4.6 and Table 4.7.

**Table 4.6: Average and Maximum Queue Length for Dhahran Street**

| S.No. | Intersection | Approach | Field Average Queue Length (m) | Field Maximum Queue Length (m) |
|---|---|---|---|---|
| 1 | Makkah Street Intersection | From Dhahran | 55.9 | 63 |
| 2 | Makkah Street Intersection | From Khobar | 21.2 | 36 |
| 3 | Hamoud Street Intersection | From Dhahran | 52.7 | 63 |
| 4 | Hamoud Street Intersection | From Khobar | 31.5 | 36 |
| 5 | Abdul Aziz Street Intersection | From Dhahran | 39.2 | 45 |
| 6 | Abdul Aziz Street Intersection | From Khobar | 32.7 | 40.5 |

**Table 4.7: Average and Maximum Queue Length for Dammam 1st Street**

| S. No. | Intersection | Approach | Field Average Queue Length (m) | Field Maximum Queue Length (m) |
|---|---|---|---|---|
| 1 | King Khaled Intersection | From South | 31 | 40.5 |
| 2 | King Khaled Intersection | From North | 42 | 54 |
| 3 | King Saud Intersection | From South | 20 | 27 |
| 4 | King Saud Intersection | From North | 39 | 49.5 |
| 5 | King Abdul Aziz Intersection | From South | 29 | 36 |
| 6 | King Abdul Aziz Intersection | From North | 17 | 22.5 |

### 4.4.5 Saturation Flow

Saturation flow is the number of vehicles that can pass a given point on a roadway in a given period of time. In studies of intersections it would be focused on the flow past the stop bar in a lane in an hour of uninterrupted green signal. Saturation flow rate for this study was calculated as a sample to use in the model for its calibration.

Saturation flow data is collected at an intersection during the period of 3:45 pm to 4:45 pm using a stop watch. The observer started the stop watch when the rear axle of the fourth vehicle in a queue that had been stationary while waiting for the green signal had crossed the stop bar. The observer stopped the stop watch when the rear axle of the seventh, eighth, ninth, or tenth vehicle in the queue (whichever was the last vehicle in the stopped queue at the instant the signal turned green) had crossed the stop bar. The observer cannot record a measurement if the queue is less than seven vehicles long when the signal turns green because short queues provide unstable data. If the queue is more than 10 vehicles long, the observer stops the watch at the tenth vehicle. Ten vehicles is a convenient maximum that decreases the chances of error due to the effects of spillback or due to vehicles stopping for the signal. Observer ignored the vehicles joining the queue after the green signal appeared. One observer recorded saturation data for one lane at a time. Saturation flow rates estimated for a lane usually apply to adjacent lanes of the same type on the same approach. Mean saturation flow rate was estimated by calculating an average number of seconds consumed per vehicle (i.e., headway) and converting that into a number of vehicles per hour. The existing saturation flow obtained from the field is 1925 veh/h/l. Field observed saturation flow rate is attached in Appendix B.

### 4.4.6 Signal Control Data

Signal control data as said earlier consists of cycle lengths, phases, splits, and offsets. Cycle lengths, phases, and splits of each intersection for both the networks are recorded using stopwatch. Cycle length is the time required for one complete sequence of signal indications (phases), i.e., the time from green indication to again green indication. Usually it is measured in seconds. Cycle length for all the three signalized intersections of Dhahran Street are recorded as 135 seconds. Cycle length for the first two intersections that are connecting Dammam 1$^{st}$ Street with King Khaled Street and King Saud Street were found to be 180 seconds, where as the third one that is connecting with the King Abdul Aziz Street was found to be 90 seconds.

Phase is defined as the part of a cycle length allocated to any combination of one or more traffic movements simultaneously receiving the right of way during one or more intervals. Split is defined as the percentage of a cycle length allocated to each of the various phases in a signal sequence. Offset is the time difference between the start of the green indication at one intersection for a specific direction as related to the start of green indication at another intersection for the same direction or from system time base. Offsets were determined using stop-watches and mobiles. The existing signal control data for all the intersections were recorded from the field to supply as an input to the VISSIM model.

## 4.5 Schedule of Activities

The first of all activities in this study was to get familiar with the VISSIM model, to know about its input and output characteristics, to learn network coding, and to run simulation. Then about a week was devoted to select the two networks that have the same cycle lengths or multiple of cycle lengths. One network found in Khobar is used for calibration of model and other network found in Dammam is used for validation of model. Data for the calibration network was collected in first week of October 2004 and the data for the validation network was collected in December 2004. During these months the weather was normal and there were no abnormal conditions that could have affected the traffic characteristics in these study areas.

About 25 M.S. students studying in KFUPM were employed to smoothly conduct this data collection task. All of these students had previous experience in collecting traffic data and in addition to it they were all extensively trained to collect the data needed in this study. In both the cities data were collected between 3:45 pm and 4:45 pm, it was not a study requirement but it’s a coincidence. All the data needed for this study such as traffic volume, average travel time, average link speed and average and maximum queue length from both the networks were collected during this one hour period to avoid any form of inconsistency in comparing these data to the model simulation output.

# CHAPTER 5

# DATA ANALYSIS

## 5.1 Introduction

The process of preparing a VISSIM traffic simulation generally involves preparing a model of existing conditions, calibrating the model against actual traffic conditions, validating the model by implementing the calibrated parameters on another existing network, and then reducing the output and arriving at conclusions. The process is similar to a scientific experiment because different networks are compared to represent a valid conclusion.

## 5.2 Data Input\Network Coding

The first task in the calibrating and validating the VISSIM model was creating the study network for each mission. For the purpose of simulating traffic operations, it is necessary to replicate the modeled infrastructure network to scale. To attain this, base maps in a bit map format were imported and used to exactly trace a network in VISSIM. Study networks were built based on the road geometry and infrastructure maps. Street networks are created in VISSIM through a series of links and connectors. Links are generally straight or follow the curvature of the road. Connectors, which are used to connect links, are typically used to model turning areas and lane expansions and contractions. In VISSIM, the creation of street networks is fairly simple through the use of a graphical interface and an aerial photograph in the background.

Creating a street network in VISSIM is not as fast or convenient as creating a network in SYNCHRO, which can then be exported to a SIMTRAFFIC or CORSIM network. For example, drawing two intersecting links in SYNCHRO automatically creates a full intersection where vehicles can make multiple maneuvers (i.e. left-turns, right-turns, etc.). However, in VISSIM, two intersecting links does not automatically create a full intersection. The links only represent through traffic, and all left-turn and right-turn maneuvers need to be coded separately by connectors, which follow the path of the desired maneuver. To model a typical four-legged intersection in VISSIM, two links plus eight connectors need to be coded. The time required to model a typical intersection in VISSIM is easily 10 times longer than modeling a typical intersection in SYNCHRO.

The vehicle population in VISSIM is categorized into *vehicles types*. A single type gathers vehicles that share common vehicle performance attributes. These attributes include model, minimum and maximum acceleration, minimum and maximum deceleration, weight, power, and length. All of these, except for model and length, are defined in VISSIM with probabilistic distributions (as opposed to scalars). Since no trucks were found on the study networks only one vehicle type called CAR was created to model the networks. Therefore traffic composition proportion was defined as 100% CAR. The vehicle specification for this type is identical to that of the default CAR type in VISSIM.

Traffic volume data, which includes input flow rates, turning movements at intersections, and traffic composition, were provided from the field.

A typical VISSIM run of the existing conditions model used for this study took an average 20 to 30 minutes to simulate a 1 hour and 15 minute simulation. The first 15 minutes were used to initialize the model. Statistics were gathered for the VISSIM runs only after the initial 15-minute period had elapsed. Pictures of a part of two different coded networks in two different modes are shown below in Figures 5.1, 5.2, 5.3 and 5.4.

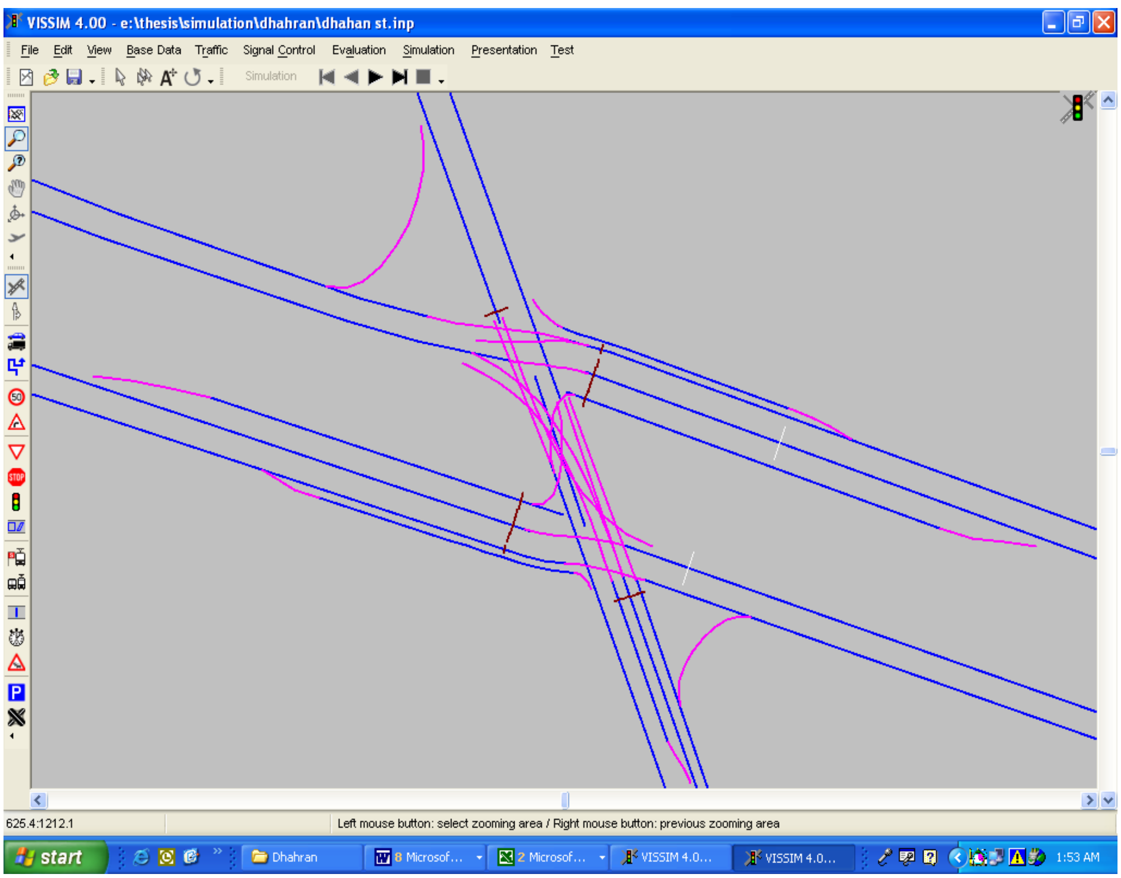


**Figure 5.1: Coded Dhahran Street in Link Connector Mode**

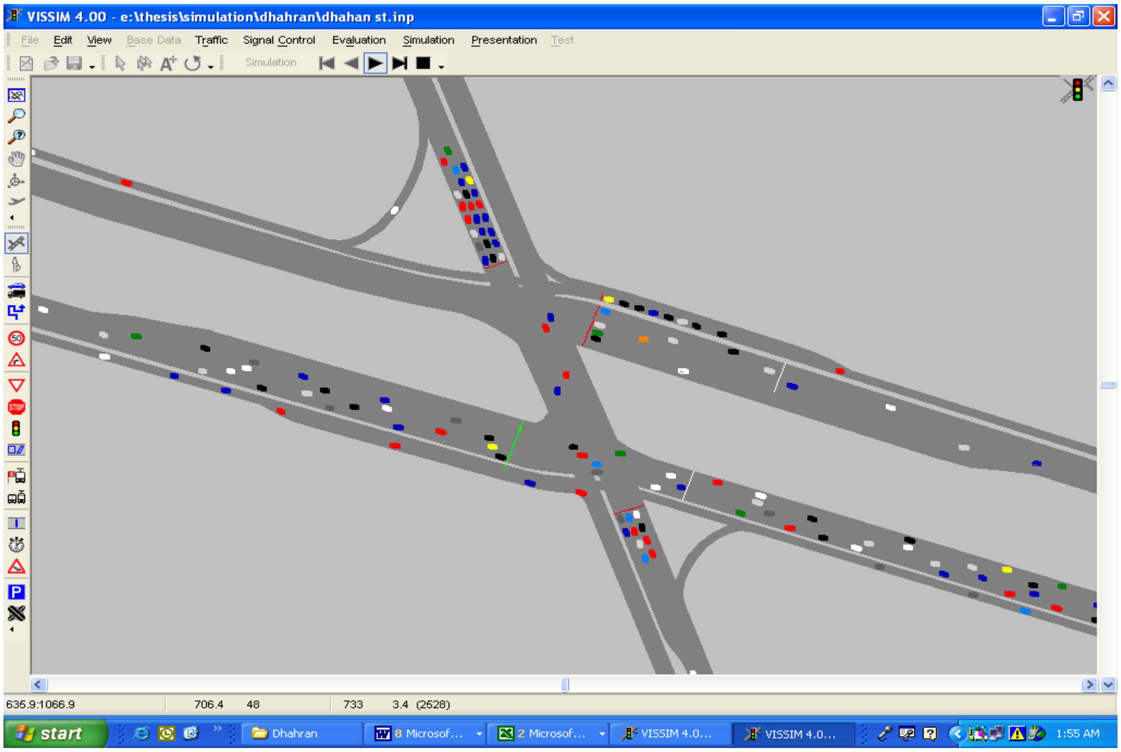


**Figure 5.2: Dhahran Street during Simulation**

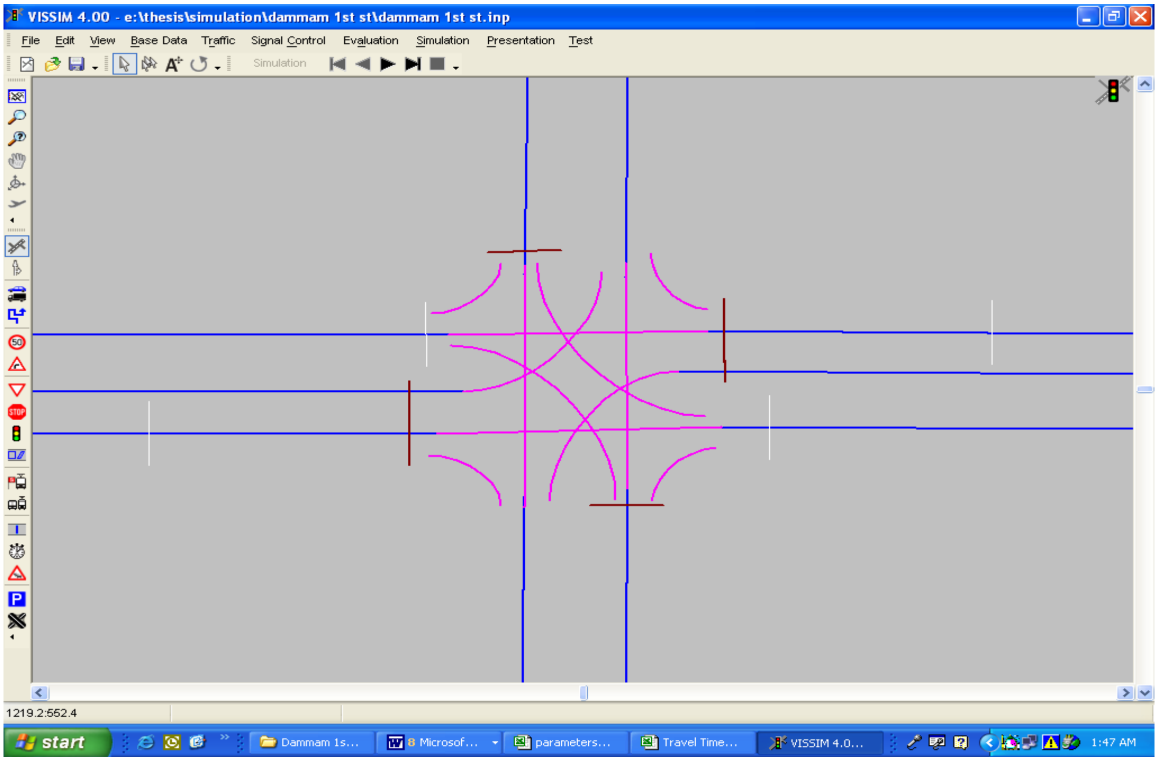


**Figure 5.3: Coded Dammam 1st Street in Link Connector Mode**

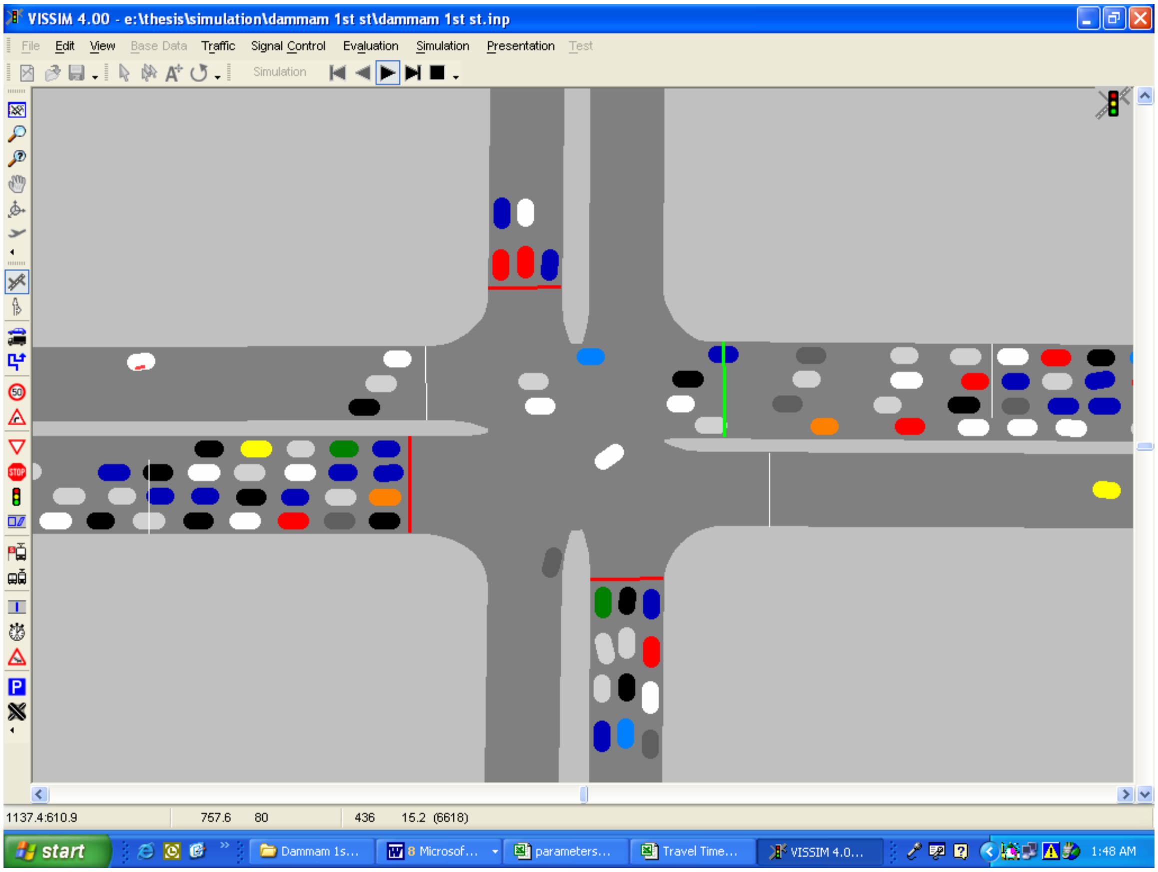


**Figure 5.4: Dammam 1st Street during Simulation**

## 5.3 Model Verification

Any microscopic model must be verified after network coding and before proceeding further. Verification involves examination of coded network to ensure that the coded network represents actual conditions. A series of simulation runs were conducted to determine if the model is functioning as intended. VISSIM allow on-line viewing of the simulation runs. These verification runs revealed network coding errors such as lack of right turns on red, excessive speeds around corners, and lack of connection between links. It also should be noted that the network coding errors are major source of abnormal vehicular movements. Such errors can be found at any time during the process of the calibration. Accordingly, fixing network coding errors is an important task throughout the whole calibration process.

## 5.4 Determination of Number of Simulation Runs

VISSIM is a stochastic simulation model, which rely upon random numbers to release vehicles, assign vehicle type, select their destination and their route, and to determine their behaviors as the vehicles move through the network. Therefore, multiple simulation runs using different seed numbers are required and the median simulation run (based on a user-specified measure) or the average results of several simulation runs can reflect the average traffic condition of a specific scenario. The flow chart to determine the number of simulation runs is shown in Figure 5.5.

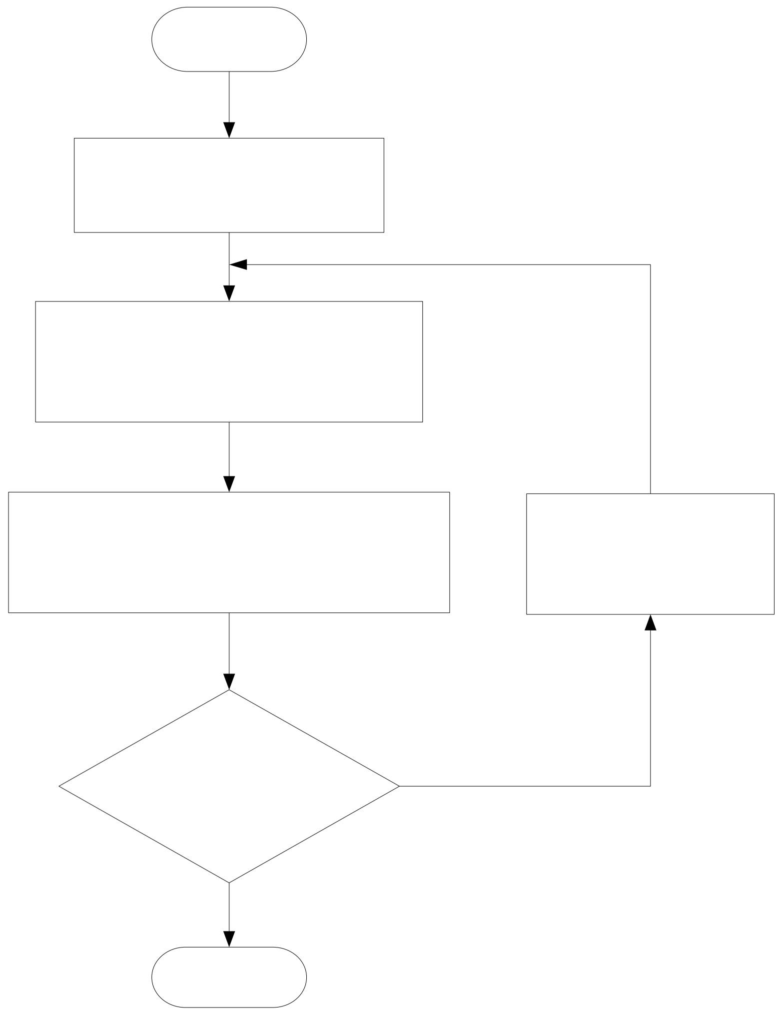

**Figure 5.5: Flow Chart of the determination of number of simulation runs**

In order to determine the number of simulation runs, we need to know the variance of a number of performance measures from simulation results, which are unknown before simulations. All performance measures of interest are needed to be involved in this calculation and the highest value is the required number of runs. If the current number of runs is already larger than this value, the simulation of this scenario is ended. Otherwise, one additional run is performed and then the required number of runs needs to be recalculated. Initially ten simulation runs were executed and then the required number of runs was calculated according to the mean and standard deviation of a performance measure of these runs (Lianyu Chu *et al* 2004):

$$N = (t_{\alpha/2} \cdot \frac{\delta}{\mu . \varepsilon})^2$$

where $\mu$ and $\delta$ are the mean and standard deviation respectively of the performance measure based on the already conducted simulation runs; $\varepsilon$ is the allowable error specified as a fraction of the mean $\mu$; $t_{\alpha/2}$ is the critical value of the t-distribution at the confidence interval of 1-$\alpha$. A 90% confidence interval and a 5% allowable error were used in the calculation. Initial ten number of simulation runs was found to be large enough for all the performance measures that were considered. Average of these results was considered when comparing with the performance measures collected on the field.

# CHAPTER 6

# CALIBRATION AND VALIDATION OF THE MODEL

## 6.1 Calibration of the Model

Calibration is the process by which the individual components of the simulation model are refined and adjusted so that the simulation model accurately represents field measured or observed traffic conditions. With regards to calibration, traffic simulation models contain numerous variables to define and replicate traffic control operations, traffic flow characteristics, and driver behavior. VISSIM simulation model contains default values for each variable (see Table 6.1), but also allows a range of user-applied values for each variable. In some cases, the variables affect the entire network while others are specific to individual roadway segments or nodes. Changes to these variables during calibration should be based on field-measured or observed conditions. In other words, a change in the variables should be justified and defensible.

Unluckily, the user manual for VISSIM simulation model provide little or no information about the source or appropriateness of the default parameters, nor do it provide substantial guidance on how the user should modify these parameters for different types of conditions. Therefore, the user has a greater responsibility for ensuring that appropriate changes are made that are based on field-measured data and not exclusively on engineering judgment.

**Table 6.1: VISSIM Default Values (PTV 2004)**

| S.no | Model | Parameters | | Default values |
|---|---|---|---|---|
| 1 | Car following Model | Look ahead Distance | Min | 0 m |
| 2 | | | Max | 250 m |
| 3 | | Observed number of Vehicles | | 2 No's |
| 4 | | Temporary Lack of Attention | Duration | 0 |
| 5 | | | Probability | 0 % |
| 6 | Wiedemann 74 | Average Standstill distance | | 2 m |
| 7 | | Additive Part of Desired Safety Distance | | 2 |
| 8 | | Multiplicative Part of Desired Safety Distance | | 3 |
| 9 | Lane Change Behavior | General behavior | Free Lane Selection or Right side rule | Free Lane Selection |
| 10 | | Waiting Time before Diffusion | | 60 sec |
| 11 | | Minimum Headway (front/rear) | | 0.5 m |
| 12 | | Necessary Lane Change (Route) | Own Vehicle | - 4 $m/s^2$ |
| 13 | | | Trailing Vehicle | - 3 $m/s^2$ |
| 14 | | | Own Vehicle | -1 $m/s^2$ per 100 m |
| 15 | | | Trailing Vehicle | -1 $m/s^2$ per 100 m |
| 16 | | | Own Vehicle | -1 $m/s^2$ |

| S.no | Model | Parameters | | Default values |
|---|---|---|---|---|
| 17 | | | Trailing Vehicle | -1 $m/s^2$ |
| 18 | Lateral Behavior | Desired Position at Free Flow: Middle of Lane; Any; or Right/Left | | Middle of Lane |
| 19 | | Observe Vehicles on next lane(s) | | Optional |
| 20 | | Overtake on same lane: on left/on right | | Optional |
| 21 | | Minimum Lateral Distance | At 0 km/h | 1 m |
| 22 | | | At 50 km/h | 1 m |
| 23 | Amber Signal Decision Model | Continuous check or One Decision | | Continuous check |
| 24 | Driver's Behavior | Maximum acceleration | | 3.5 $m/s^2$ |
| 25 | | Desired acceleration | | 3.5 $m/s^2$ |
| 26 | | Maximum deceleration | | Between -7.5 $m/s^2$ and -5.1 $m/s^2$ |
| 27 | | Desired deceleration | | Between -2.8 $m/s^2$ and -2.8 $m/s^2$ |
| 28 | Simulation | Time Step | | 5 |
| 29 | Vehicle Attribute | Desired Speed | | |
| 30 | Connector Attributes | Emergency Stop | | 5 m back |
| 31 | | Lane change | | 200 m back |

### 6.1.1 Description of Model Parameters

*Car following model* selects the basic model for the vehicle following behavior (PTV 2004).

- *Wiedemann 74*: Model mainly suitable for urban traffic. This model is an improved version of Wiedemann's 1974 car following model. The following parameters are available in this model:
- *Average Standstill Distance* defines the average desired distance between stopped cars. It has a fixed variation of ± 1m.
- *Additive Part of Desired Safety Distance* and *Multiplicative Part of Desired Safety Distance* affect the computation of the safety distance. These are the main parameters to affect the capacity flow.
- The *Look ahead distance* defines the distance that a vehicle can see forward in order to react to other vehicles either in front or to the side of it (within the same link).
    - The *maximum* is the maximum distance allowed for looking ahead. It needs to be extended only in rare occasions (e.g. for modeling railways if signals and stations are to be recognized in time).
- The Number of *Observed Vehicles* affects how well vehicles in the network can predict other vehicles movements and reacts accordingly. As some of the network elements are internally modeled as vehicles it might be useful to

increase this value if there are several cross sections of network elements within a short distance. However, the simulation will run slower with higher values.

- *Temporary lack of attention* ("sleep" parameter): Vehicles will not react to a preceding vehicle (except for emergency braking) for a certain amount of time. The higher both of these below parameters are, the lower the capacity on the corresponding links will be.
    - *Duration* defines, how long this lack of attention occurs
    - *Probability* defines how often this lack of attention occurs

*Lane change Behavior*

- *General Behavior*: Defines the way of overtaking:
    - *Free Lane Selection:* Vehicles are allowed to overtake in any lane
    - *Right Side Rule* resp. *Left Side Rule:* Allows overtaking in the fast lane only if speed in the fast lane is above 60 km/h. For slower speeds, vehicles in the slow lane are allowed to "undertake" with a max. speed difference of 20 km/h
- *Waiting time before diffusion* defines the maximum amount of time a vehicle can wait at the emergency stop position waiting for a gap to change lanes in order to stay on its route. When this time is reached the vehicle is taken out of the network (diffusion) and a message will be written to the error file denoting the time and location of the removal.

- *Min. Headway (front/rear)* defines the minimum distance to the vehicle in front that must be available for a lane change in standstill condition.

*Lateral Behavior:*

- *Desired position at free flow* defines the desired lateral position of a vehicle within the lane while it is in free flow. The options are: *Middle of Lane*, *Any* or *Right* resp. *Left*.
- *Observe vehicles on next lane(s):* Vehicles also consider the lateral position of other vehicles that are traveling on adjacent lanes.
- *Overtake on same lane:* Select all vehicles classes that are allowed to be overtaken within the same lane by any vehicle of that class for which this parameter set is assigned. You can define also on which side they are to be overtaken (*on left, on right* or on both sides within the same lane).
- *Min. Lateral Distance:* Minimum distances for vehicles passing each other within the same lane are defined for each vehicle class to be passed. The distance is defined for standstill (*at 0 km/h*) as well as for *50 km/h*. For those vehicle classes where no values are defined, the default definition applies.

*Decision model*:

- *Continuous Check*: Vehicles assume that the amber light stays amber for 2 seconds and continuously decides whether to proceed at each time step thereafter until passing the signal head.

- *One Decision*: Three parameters (*Alpha*, *Beta 1* and *Beta 2*) are used to calculate the probability of the driver stopping at amber light. The formula is

$$p = \frac{1}{1 + e^{(-\alpha - \beta_1 . v - \beta_2 . dx)}}$$

The option *One Decision* will produce the most accurate results if the number of *Observed vehicles* is increased accordingly. This is due to the fact that a signal head internally is modeled as a vehicle and only recognized if there are no more other vehicles and network elements in front of the signal head than the number of *Observed vehicles* minus 1.

The *Emergency Stop* and *Lane change* parameters are used to model the lane change behavior for cars following their route.

*Lane change* defines the distance at which vehicles will begin to attempt to change lanes (e.g. distance of signpost prior to a junction).

*Emergency Stop* defines the last possible position for a vehicle to change lanes. If a vehicle could not change lanes due to high traffic flows but needs to change in order to stay on its route, it will stop at this position to wait for an opportunity to change lanes.

*Desired Speed:*

For any vehicle type the speed distribution is an important parameter that has a significant influence on roadway capacity and achievable travel speeds. If not hindered by other vehicles, a driver will travel at his desired speed (with a small stochastic variation called oscillation). The more vehicles differ in their desired speed, the more platoons are created. If overtaking is possible, any vehicle with a higher desired speed than its current travel speed is checking for the opportunity to pass without endangering other vehicles, of course.

Under ideal conditions, the calibration of individual components of a simulation model will improve the simulation model's ability to replicate traffic flow results that match field conditions within an acceptable range of error. Typical traffic flow characteristics that were used in validation include average travel time, average link speed, average queue length and maximum queue length. Unfortunately, professional guidelines that define the acceptable range of error for these characteristics have not been developed. Instead, transportation professionals have either ignored the need for validation or developed their own guidelines (Fred *et al* 2002). The validation guidelines used in recent projects by the authors and accepted by agencies such as Caltrans were considered for this study and they are shown in Table 6.2.

**Table 6.2: Validation Guidelines Used in Study (Fred *et al* 2002)**

| **Validation Guidelines** | | |
|---|---|---|
| **Parameters** | **Description** | **Validation Criteria** |
| Average Travel Time | Standard Deviation between floating car average travel times and simulated average travel time for a series of links | 1 Standard Deviation |
| Average Travel Speed | Standard Deviation between floating car average travel speed and simulated average travel speed for individual links | 1 Standard Deviation |
| Average and Maximum Vehicle Queue Length | Percent difference between observed queue lengths and simulated queue lengths | 80 to 120 % of observed value |

As in any other simulation model, VISSIM also contains a number of parameters that represent the driving behavior characteristics in the country where the model is originally introduced and calibrated. It is well known that such characteristics can vary significantly from one society to another. Therefore, the successful utilization of any traffic simulation model depends on selecting the proper values of the parameters that describe the driver performance characteristics in the area where the model is to be used. In the VISSIM simulation model, these parameters are in abundant as described above. Considering all these parameters for calibration was tedious job. Therefore, the parameters such as vehicle acceleration and deceleration, etc., were disregarded because the vehicle type, vehicle class and vehicle model used in Saudi Arabia are same as that used in VISSIM model.

More emphasize was done on the parameters which deals with the driving behavior such as number of observed vehicles, additive and multiplicative part of desired safety distance, amber signal decision model and distance required in changing lane (see Table 6.3). Since these parameters are directly related to the driving behavior, each parameter is calibrated separately. After studying the affect of these parameters some sets of values for these parameters were made and calibration was performed based on these parameters values.

**Table 6.3: Parameters considered for calibration**

| S.No | Parameters | VISSIM Default Values |
|---|---|---|
| **1** | **No. of Observed Vehicles** | 2 |
| **2** | **Additive Part of Desired Safety Distance** | 2 |
| **3** | **Multiplicative Part of Desired Safety Distance** | 3 |
| **4** | **Amber Signal Decision Model** | Continuous Check |
| **5** | **Lane Change Distance** | 200 m |

***Observed vehicles*:** This parameter is related to urban driver car-following model. The number of *Observed Vehicles* affects how well vehicles in the network can predict other vehicles movements and reacts accordingly. Since in VISSIM, some of the network elements are internally modeled as vehicles it might be useful to increase this value because there are several cross sections of network elements within a short distance. However, the rate of simulation decreases as this value increases.

***Additive and Multiplicative part of desired safety distance*:** These two parameters *Additive Part of Desired Safety Distance* and *Multiplicative Part of Desired Safety Distance* contained within the Weidemann 74 Car-Following Model have major influence on the safety distance and thus affect the saturation flow rate. In VISSIM the saturation flow is a result of a combination of these parameters which are relevant for the simulation. Thus the saturation flow cannot be explicitly defined but can change these relevant driving behavior parameters in order to get a different saturation flow rate. The saturation flow rate defines the number of vehicles that can free flow through a VISSIM model during one hour. With the default values of these parameters VISSIM model gives the saturation flow equal to 2050 veh/h/l, whereas the existing saturation flow obtained from the field is 1925 veh/h/l. therefore the calibration of these parameters were considered.

***Amber signal decision model*:** This model is also related to the driving behavior, it defines the driver's reaction to amber signal. VISSIM has two options continuous check and one decision.

- *Continuous Check*: Vehicles assume that the amber light stays amber for 2 seconds and continuously decides whether to proceed at each time step thereafter until passing the signal head.
- *One Decision*: VISSIM calculates the probability of the driver stopping at amber light. The option *One Decision* will produce the most accurate results if the number of *Observed vehicles* is increased accordingly. This is due to the fact that a signal head internally is modeled as a vehicle and only recognized if there are no more other vehicles and network elements in front of the signal head than the number of *Observed vehicles* minus 1.

***Look-back distance*:** This is a parameter related to Necessary lane change behavior, which dictates how far in advance each vehicle will be able to anticipate the next bifurcation (i.e. off ramp) or lane drop, and how aggressively that vehicle will begin maneuvering towards the desired lane.

### 6.1.2 Comparing Simulated Results and Field Observed MOE's

To start with, an initial simulation experiment was run on the network of Dhahran Street using default driving behavior parameters values. Average of ten simulation runs with different seed numbers for all the performance measures that considered for output was taken and they are compared with the field observed average travel time, average link speed, and average and maximum queue length. Comparison tables of these measures of effectiveness are shown below in Table 6.4 through Table 6.7.

**Table 6.4: Comparison of Field Avg Travel Time and VISSIM Default Travel Time**

| S.No | Route | Segment Distance (m) | Field Travel Time (s) | Std-Dev | VISSIM Default Travel Time (s) | Between 1 Standard Deviation |
|---|---|---|---|---|---|---|
| 1 | Makkah Street Intersection to Hamoud Street Intersection | 735 | 59 | 4.561 | 54.125 | NO |
| 2 | Hamoud Street Intersection to Abdul Aziz Street Intersection | 985 | 68 | 4.775 | 62.21 | NO |
| 3 | Abdul Aziz Street Intersection to Hamoud Street Intersection | 1000 | 73 | 3.742 | 68.718 | NO |
| 4 | Hamoud Street Intersection to Makkah Street Intersection | 750 | 55 | 3.795 | 49.578 | NO |
| 5 | Makkah Street Intersection to Abdul Aziz Street Intersection | 1873.5 | 188 | 4.69 | 183 | NO |
| 6 | Abdul Aziz Street Intersection to Makkah Street Intersection | 1898.2 | 168 | 5.02 | 162.16 | NO |

**Table 6.5: Comparison of Field Avg Link Speed and VISSIM Default Link Speed**

| S.No | Link | Field Average Speed Km/h | Std-Dev | VISSIM Default Average Speed Km/h | Between 1 Standard Deviation |
|---|---|---|---|---|---|
| 1 | Makkah Street Intersection to Hamoud Street Intersection | 46.2 | 2.93 | 50.21 | NO |
| 2 | Hamoud Street Intersection to Abdul Aziz Street Intersection | 52.15 | 3.06 | 56.0975 | NO |
| 3 | Abdul Aziz Street Intersection to Hamoud Street Intersection | 50.15 | 2.4 | 52.7318 | NO |
| 4 | Hamoud Street Intersection to Makkah Street Intersection | 57.45 | 2.66 | 54.5108 | NO |

**Table 6.6: Comparison of Field and VISSIM Default Avg Queue Length**

| S.No | Intersection | Approach | Field Average Queue Length (m) | VISSIM Default Average Queue Length (m) | Variation % | 80 to 120% of Field Value |
|---|---|---|---|---|---|---|
| 1 | Makkah Street Intersection | From Dhahran | 55.9 | 51.7 | 7.513 | YES |
| 2 | Makkah Street Intersection | From Khobar | 21.2 | 23.2 | -9.43 | YES |
| 3 | Hamoud Street Intersection | From Dhahran | 52.7 | 58.8 | -11.6 | YES |
| 4 | Hamoud Street Intersection | From Khobar | 31.5 | 33.8 | -7.3 | YES |
| 5 | Abdul Aziz Street Intersection | From Dhahran | 39.2 | 40.8 | -4.08 | YES |
| 6 | Abdul Aziz Street Intersection | From Khobar | 32.7 | 27.5 | 15.9 | YES |

**Table 6.7: Comparison of Field and VISSIM Default Maximum Queue Length**

| S.No | Intersection | Approach | Field Maximum Queue Length (m) | VISSIM Default Maximum Queue Length (m) | Variation % | 80 to 120% of Field Value |
|---|---|---|---|---|---|---|
| 1 | Makkah Street Intersection | From Dhahran | 63 | 78.2 | -24.1 | NO |
| 2 | Makkah Street Intersection | From Khobar | 36 | 25.6 | 28.9 | NO |
| 3 | Hamoud Street Intersection | From Dhahran | 63 | 76.5 | -21.4 | NO |
| 4 | Hamoud Street Intersection | From Khobar | 36 | 44.3 | -23.1 | NO |
| 5 | Abdul Aziz Street Intersection | From Dhahran | 45 | 58.8 | -30.7 | NO |
| 6 | Abdul Aziz Street Intersection | From Khobar | 40.5 | 31.2 | 23 | NO |

After simulating the network with VISSIM default values as shown in above section, it was found that none of the performance measure is matching with the field observed MOE's except the average queue length is within the validation criterion this is because the validation criterion is broad enough which ranges 20%. Therefore a set of parameter values for calibration were considered as shown below in Table 6.8 and network is simulated using these parameter values. Field observed MOE's average travel time, average link speed, and average and maximum queue length were compared with the corresponding MOE of the simulated results using these set of parameters values (see Tables 6.9 through 6.12). If the comparison is with in the validation criteria then the model is said to be validated, otherwise the model is calibrated again to decrease the discrepancy between calculated and observed measures of effectiveness. This results in an iterative process until we reach convergence. From the summary of simulation results with the set of parameters as shown below in different MOE tables it is found that set 8 is the best matching with the field observed MOE's. Now the next step was to check the validity of these calibrated values by implementing them on another network chosen in Dammam.

**Table 6.8: Set of Parameter Values Used in Calibration**

| S.No | Parameters | VISSIM Default Values | Calibrated Parameter Values | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Set 1 | Set 2 | Set 3 | Set 4 | Set 5 | Set 6 | Set 7 | Set 8 |
| **1** | **No. of Observed Vehicles** | 2 | 4 | 2 | 2 | 2 | 2 | 4 | 4 | 4 |
| **2** | **Additive Part of Desired Safety Distance** | 2 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 |
| **3** | **Multiplicative Part of Desired Safety Distance** | 3 | 3.25 | 3.25 | 3.25 | 3.25 | 3.25 | 3.25 | 3.25 | 3.25 |
| **4** | **Amber Signal Decision Model** | Continuous Check | One Decision | One Decision | Continuous Check | One Decision | Continuous Check | Continuous Check | One Decision | Continuous Check |
| **5** | **Lane Change Distance** | 200 m | 300 m | 300 m | 300 m | 200 m | 200 m | 300 m | 200 m | 200 m |

**Table 6.9: Average Travel Time with Set of Parameter Values**

| S.No | Route | Distance (m) | Field Travel Time (s) | STD-DEV | VISSIM Default Travel Time (s) | 1 Std Dev | Calibrated Travel Time (s) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Set 1 | 1 Std Dev | Set 2 | 1 Std Dev | Set 3 | 1 Std Dev | Set 4 | 1 Std Dev | Set 5 | 1 Std Dev | Set 6 | 1 Std Dev | Set 7 | 1 Std Dev | Set 8 | 1 Std Dev |
| 1 | Makkah St Int to Hamoud St Int | 735 | 59 | 4.56 | 54.12 | NO | 54.9 | YES | 53.88 | NO | 54.99 | YES | 54.20 | NO | 55 | YES | 55.29 | YES | 55.44 | YES | 56.1 | YES |
| 2 | Hamoud St Int to Abdul Aziz St Int | 985 | 68 | 4.77 | 62.21 | NO | 62.42 | NO | 61.7 | NO | 61.8 | NO | 62.48 | NO | 62.44 | NO | 62.55 | NO | 63.01 | NO | 63.4 | YES |
| 3 | Abdul Aziz St Int to Hamoud St Int | 1000 | 73 | 3.74 | 68.78 | NO | 69.87 | YES | 68.97 | NO | 69 | NO | 68.94 | NO | 69 | NO | 69.79 | YES | 69.85 | YES | 69.8 | YES |
| 4 | Hamoud St Int to Macca St Int | 750 | 55 | 3.79 | 49.57 | NO | 50.86 | NO | 49.48 | NO | 49.49 | NO | 49.86 | NO | 49.94 | NO | 50.9 | NO | 51.13 | NO | 51.2 | YES |
| 5 | Makkah St Int to Ab. Aziz St Int | 1873.5 | 188 | 4.69 | 183 | NO | 182.8 | NO | 181.6 | NO | 182.9 | NO | 182.37 | NO | 183.9 | YES | 184.59 | YES | 183.96 | YES | 185 | YES |
| 6 | Ab. Aziz St Int to Makkah St Int | 1898.2 | 168 | 5.02 | 162.16 | NO | 164.35 | YES | 162.7 | NO | 162.7 | NO | 162.70 | NO | 162.9 | NO | 164.47 | YES | 164.42 | YES | 165 | YES |

**Table 6.10: Average Link Speed with Set of Parameter Values**

| S No | Link | Field Average Speed Km/h | STD-DEV | VISSIM Default Average Speed Km/h | 1 Std Dev | Calibrated Average Speed Km/h | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Set 1 | 1 Std Dev | Set 2 | 1 Std Dev | Set 3 | 1 Std Dev | Set 4 | 1 Std Dev | Set 5 | 1 Std Dev | Set 6 | 1 Std Dev | Set 7 | 1 Std Dev | Set 8 | 1 Std Dev |
| 1 | Makkah St Int to Hamoud St Int | 46.2 | 2.93 | 50.21 | NO | 49.48 | NO | 50.39 | NO | 49.59 | NO | 50.14 | NO | 49.6 | NO | 48.83 | YES | 49.14 | NO | 48.67 | YES |
| 2 | Hamoud St Int to Abdul Aziz St Int | 52.15 | 3.06 | 56.09 | NO | 55.87 | NO | 56.44 | NO | 56.42 | NO | 55.81 | NO | 55.8 | NO | 55.76 | NO | 55.46 | NO | 55.14 | YES |
| 3 | Abdul Aziz St Int to Hamoud St Int | 50.15 | 2.4 | 52.73 | NO | 51.92 | YES | 52.55 | NO | 52.54 | YES | 52.55 | YES | 52.5 | YES | 51.98 | YES | 51.93 | YES | 51.95 | YES |
| 4 | Hamoud St Int to Makkah St Int | 57.45 | 2.66 | 54.51 | NO | 53.46 | NO | 54.61 | NO | 54.62 | NO | 54.24 | NO | 54.2 | NO | 53.38 | NO | 53.12 | NO | 53.12 | NO |

## Table 6.11: Average queue Length with Set of Parameter Values

| S.No | Intersection | Approach | Field Average Queue Length (m) | VISSIM Default Average Queue Length (m) | Var % | 80 to 120% of Field Value | Calibrated Average Queue Length (m) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Set 1 | Var % | 80 to 120% of Field Value | Set 2 | Var % | 80 to 120% of Field Value | Set 3 | Var % | 80 to 120% of Field Value | Set 4 | Var % | 80 to 120% of Field Value | Set 5 | Var % | 80 to 120% of Field Value | Set 6 | Var % | 80 to 120% of Field Value | Set 7 | Var % | 80 to 120% of Field Value | Set 8 | Var % | 80 to 120% of Field Value |
| 1 | Makkah Street Intersection | From Dhahran | 55.9 | 51.7 | 7.5 | YES | 53 | 5.2 | YES | 53.4 | 4.5 | YES | 55.1 | 1.4 | YES | 53.5 | 4.3 | YES | 55.4 | 0.9 | YES | 54.6 | 2.3 | YES | 53.1 | 5.0 | YES | 54.7 | 2.1 | YES |
| 2 | Makkah Street Intersection | From Khobar | 21.2 | 23.2 | -9.4 | YES | 22 | -3.8 | YES | 23.5 | -10.9 | YES | 23.6 | -11.3 | YES | 23.2 | -9.4 | YES | 23.2 | -9.4 | YES | 22.1 | -4.2 | YES | 21.8 | -2.8 | YES | 21.7 | -2.4 | YES |
| 3 | Hamoud Street Intersection | From Dhahran | 52.7 | 58.8 | -11.6 | YES | 57.3 | -8.7 | YES | 58.4 | -10.9 | YES | 60 | -13.9 | YES | 58.4 | -10.8 | YES | 60 | -13.9 | YES | 58.8 | -11.6 | YES | 57.9 | -9.9 | YES | 58.8 | -11.6 | YES |
| 4 | Hamoud Street Intersection | From Khobar | 31.5 | 33.8 | -7.3 | YES | 32.9 | -4.4 | YES | 34.2 | -8.6 | YES | 34.4 | -9.2 | YES | 34.2 | -8.6 | YES | 34.2 | -8.6 | YES | 33 | -4.8 | YES | 32.7 | -3.8 | YES | 32.7 | -3.8 | YES |
| 5 | Abdul Aziz Street Intersection | From Dhahran | 39.2 | 40.8 | -4.1 | YES | 40.1 | -2.3 | YES | 41.1 | -4.8 | YES | 41.5 | -5.9 | YES | 40.5 | -3.3 | YES | 40.9 | -4.3 | YES | 40.7 | -3.8 | YES | 39.8 | -1.5 | YES | 39.9 | -1.8 | YES |
| 6 | Abdul Aziz Street Intersection | From Khobar | 32.7 | 27.5 | 15.9 | YES | 27.6 | 15.6 | YES | 27.6 | 15.6 | YES | 28.1 | 14.1 | YES | 27.8 | 15.0 | YES | 28.4 | 13.2 | YES | 27.9 | 14.7 | YES | 27.6 | 15.6 | YES | 28 | 14.3 | YES |

## Table 6.12: Maximum queue Length with Set of Parameter Values

| S.No | Intersection | Approach | Field Max Queue Length (m) | VISSIM Default Max Queue Length (m) | Var % | 80 to 120% of Field Value | Calibrated Maximum Queue Length (m) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Set 1 | Var % | 80 to 120% of Field Value | Set 2 | Var % | 80 to 120% of Field Value | Set 3 | Var % | 80 to 120% of Field Value | Set 4 | Var % | 80 to 120% of Field Value | Set 5 | Var % | 80 to 120% of Field Value | Set 6 | Var % | 80 to 120% of Field Value | Set 7 | Var % | 80 to 120% of Field Value | Set 8 | Var % | 80 to 120% of Field Value |
| 1 | Makkah Street Intersection | From Dhahran | 63 | 78.2 | -24.1 | NO | 76.4 | -21.3 | NO | 72.2 | -14.6 | YES | 74.4 | -18.1 | YES | 72.8 | -15.56 | YES | 60.4 | 4.12 | YES | 56.2 | 10.8 | YES | 57.5 | 8.73 | YES | 57.1 | 9.36 | YES |
| 2 | Makkah Street Intersection | From Khobar | 36 | 25.6 | 28.89 | NO | 25.4 | 29.44 | NO | 26.5 | 26.39 | NO | 27.4 | 23.89 | NO | 28.6 | 20.56 | NO | 32.6 | 9.44 | YES | 24.4 | 32.2 | NO | 26.4 | 26.7 | NO | 32.7 | 9.17 | YES |
| 3 | Hamoud Street Intersection | From Dhahran | 63 | 76.5 | -21.4 | NO | 78.5 | -24.6 | NO | 78.5 | -24.6 | NO | 75.8 | -20.32 | NO | 70.4 | -11.75 | YES | 78.4 | -24.4 | NO | 62.1 | 1.43 | YES | 63.2 | -0.32 | YES | 66.4 | -5.4 | YES |
| 4 | Hamoud Street Intersection | From Khobar | 36 | 44.3 | -23.1 | NO | 45.5 | -26.4 | NO | 42.4 | -17.78 | YES | 40.1 | -11.39 | YES | 42.8 | -18.89 | YES | 43.8 | -21.7 | NO | 34.8 | 3.33 | YES | 34.8 | 3.33 | YES | 36.2 | -0.56 | YES |
| 5 | Abdul Aziz Street Intersection | From Dhahran | 45 | 58.8 | -30.7 | NO | 56.4 | -25.3 | NO | 54.5 | -21.11 | NO | 50.2 | -11.56 | YES | 55.5 | -23.33 | NO | 49.2 | -9.3 | YES | 44.5 | 1.11 | YES | 43.6 | 3.11 | YES | 44.9 | 0.22 | YES |
| 6 | Abdul Aziz Street Intersection | From Khobar | 40.5 | 31.2 | 22.96 | NO | 30.8 | 23.95 | NO | 28.5 | 29.63 | NO | 29.5 | 27.16 | NO | 32.6 | 19.51 | YES | 31.1 | 23.2 | NO | 31.2 | 22.96 | NO | 31.2 | 22.96 | NO | 36.4 | 10.1 | YES |

## 6.2 Validation of the Model

Model validation is typically a process related to model calibration. The model validation was proposed to conduct using a different data set of another network within the same area to check if the calibrated model parameters are suitable. Model validation was regarded as a final stage to investigate if each component adequately reproduces observed travel characteristics and overall performance of the model is reasonable.

Validation of a simulation can be a difficult process, difficult even to precisely define. In a general sense the goal of validation is to gain confidence in the ability of the model to reasonably reflect real world conditions. Validation includes testing for reasonableness, adequacy of the model structure, and model behavior against the referent system. The intent of this task is to provide confidence in the simulation approach. Ideally, a transportation simulation validation study includes comparisons of simulated results against real world data.

From the comparison Tables 6.14 through 6.17 shown below it is clearly found that the calibrated values of set 8 are very well satisfied the validation criteria. Table 6.13 shows the set 8 as the calibrated values that satisfied the validation criteria for the field observed measures of effectiveness. Hence we can say that with these calibrated values VISSIM simulation model is fully suitable to the present and future traffic conditions of Khobar and Dammam, Saudi Arabia.

**Table 6.13: Calibrated Values**

| S.No | Parameters | VISSIM Default Values | Calibrated Values |
|---|---|---|---|
| **1** | **No. of Observed Vehicles** | 2 | 4 |
| **2** | **Additive Part of Desired Safety Distance** | 2 | 2.25 |
| **3** | **Multiplicative Part of Desired Safety Distance** | 3 | 3.25 |
| **4** | **Amber Signal Decision Model** | Continuous Check | Continuous Check |
| **5** | **Lane Change Distance** | 200 m | 200 m |

**Table 6.14: Field Observed, Default, and VISSIM Calibrated Average Travel Time**

| S No | Route | Distance | Field Average Travel Time (s) | STD-DEV | VISSIM Default Travel Time (s) | Between 1 Standard Deviation | Set 8 Calibrated Travel Time (s) | Between 1 Standard Deviation |
|---|---|---|---|---|---|---|---|---|
| 1 | King Khaled Street Intersection to King Saud Street Intersection | 330.0 m | 34 | 3.74166 | 28.8 | NO | 30.9 | YES |
| 2 | King Saud Street Intersection to King Abdul Aziz Street Intersection | 350.0 m | 32 | 2.60768 | 28.9 | NO | 31.425 | YES |
| 3 | King Abdul Aziz Street Intersection to King Saud Street Intersection | 350.0 m | 42 | 3.74166 | 40 | YES | 42.125 | YES |
| 4 | King Saud Street Intersection to King Khaled Street Intersection | 320.0 m | 47 | 2.60768 | 43.4 | NO | 46.275 | YES |
| 5 | King Khaled Street Intersection to King Abdul Aziz Street Intersection | 761.4 m | 91 | 3.03315 | 83.975 | NO | 88.325 | YES |
| 6 | King Abdul Aziz Street Intersection to King Khaled Street Intersection | 759.2 m | 108 | 3.03315 | 102.775 | NO | 109.8 | YES |

**Table 6.15: Field Observed, Default, and VISSIM Calibrated Average Link Speed**

| S No | Link | Field Average Speed Km/h | STD-DEV | VISSIM Default Average Speed Km/h | Between 1 Standard Deviation | Set 8 Calibrated Average Speed Km/h | Between 1 Standard Deviation |
|---|---|---|---|---|---|---|---|
| 1 | King Khaled Street Intersection to King Saud Street Intersection | 32 | 2.607681 | 39.9 | NO | 30.94 | YES |
| 2 | King Saud Street Intersection to King Abdul Aziz Street Intersection | 39 | 2.8982753 | 43.68 | NO | 40.835 | YES |
| 3 | King Abdul Aziz Street Intersection to King Saud Street Intersection | 33 | 3.0331502 | 31.833 | YES | 30.168 | YES |
| 4 | King Saud Street Intersection to King Khaled Street Intersection | 29 | 2.1908902 | 32.468 | NO | 30.423 | YES |

**Table 6.16: Field Observed, Default, and VISSIM Calibrated Average Queue Length**

| S. No | Intersection | Approach | Field Average Queue Length (m) | VISSIM Default Average Queue Length (m) | Variation % | 80 to 120% of Field Value | Set 8 Calibrated Average Queue Length (m) | Variation % | 80 to 120% of Field Value |
|---|---|---|---|---|---|---|---|---|---|
| 1 | King Khaled Intersection | From South | 31 | 27 | 12.9 | YES | 28 | 9.677 | YES |
| 2 | King Khaled Intersection | From North | 42 | 47 | -11.9 | YES | 49 | -16.7 | YES |
| 3 | King Saud Intersection | From South | 20 | 23 | -15 | YES | 18 | 10 | YES |
| 4 | King Saud Intersection | From North | 39 | 44 | -12.8 | YES | 46 | -17.9 | YES |
| 5 | King Abdul Aziz Intersection | From South | 29 | 33 | -13.8 | YES | 34 | -17.2 | YES |
| 6 | King Abdul Aziz Intersection | From North | 17 | 20 | -17.6 | YES | 19 | -11.8 | YES |

**Table 6.17: Field Observed, Default, and VISSIM Calibrated Maximum Queue Length**

| S. No | Intersection | Approach | Field Maximum Queue Length (m) | VISSIM Default Maximum Queue Length (m) | Variation % | 80 to 120% of Field Value | Set 8 Calibrated Maximum Queue Length (m) | Variation % | 80 to 120% of Field Value |
|---|---|---|---|---|---|---|---|---|---|
| 1 | King Khaled Intersection | From South | 40.5 | 32 | 20.99 | NO | 36 | 11.11 | YES |
| 2 | King Khaled Intersection | From North | 54 | 66 | -22.2 | NO | 50 | 7.407 | YES |
| 3 | King Saud Intersection | From South | 27 | 34 | -25.9 | NO | 31 | -14.8 | YES |
| 4 | King Saud Intersection | From North | 49.5 | 62 | -25.3 | NO | 56 | -13.1 | YES |
| 5 | King Abdul Aziz Intersection | From South | 36 | 45 | -25 | NO | 42 | -16.7 | YES |
| 6 | King Abdul Aziz Intersection | From North | 22.5 | 26 | -15.6 | YES | 26 | -15.6 | YES |

# CHAPTER 7

# SUMMARY AND CONCLUSIONS

## 7.1 Summary

The main objective of this study was to select a state of the art simulation tool for serving the traffic in Saudi Arabia, and then to test and assess the applicability of this selected simulation tool to best fit the traffic conditions in the cities of Khobar and Dammam, Saudi Arabia.

With the increasing complexity and magnitude of urban signal networks, manual traffic evaluation is an impossible task to perform. An exhaustive research of the literature was conducted to identify different simulation models. The advantages and disadvantages of these models were studied. The features of these models were compared and it was concluded that VISSIM microscopic simulation model is the best candidate for application to the present and future traffic conditions in Saudi Arabia.

In any simulation model there exists a number of parameters that represent the driving behavior characteristics in the country where the model is originally introduced and calibrated. It is well known that such characteristics can vary significantly from one society to another. Therefore, the successful utilization of any traffic simulation model depends on selecting the proper values of the parameters that describe the driver performance characteristics in the area where the model is to be used.

In the selected VISSIM simulation model, these parameters are in abundant as described in chapter five. Considering all those parameters for calibration was tedious job. Therefore, parameters which show little or no affective such as vehicle acceleration and deceleration, etc., were disregarded because the vehicle type, vehicle class and vehicle model used in Saudi Arabia are same as that used in VISSIM model.

More emphasized was done on the parameters which deals with the driving behavior such as number of observed vehicles, additive and multiplicative part of desired safety distance, amber signal decision model and distance required in changing lane. Since these parameters are directly related to the driving behavior, each parameter is calibrated separately. After studying the affect of these parameters some sets of values for these parameters were made and calibration was performed based on these parameters values.

To select the study networks for this analysis, the road networks in each Khobar and Dammam city was investigated. One criterion used in selecting the study networks was that the chosen networks should have only one common cycle length or a multiple of this common cycle length. This criterion is not a mandatory for the VISSIM model. It can simulate any type of network and can also simulate a network with even different cycle lengths or a multiple of common cycle length. To avoid any form of discrepancy in collecting measures of effectiveness from the field, especially for queue length and travel time this criterion has been recommended.

Two arterials one from Khobar and another from Dammam were found satisfying the criterion of a common cycle length. Khobar arterial is a Dhahran Street section consisted of three signalized intersections connecting Makkah Street, Prince Hamoud Street and King Abdul Aziz Street. All these intersections have a common cycle length of 135 seconds. This Dhahran Street was considered for the study of model calibration. It consists of four lanes in each direction, and it is located in mixed residential and commercial area. Dammam arterial is a 1$^{st}$ Street section located in the center of the city. It contains three lanes in each direction and it is also located in a mixed residential and commercial area. It was considered for the study of model validation. It is consisted of three signalized intersections connecting King Khaled Street, King Saud Street and King Abdul Aziz Street. Intersections connecting King Khaled Street and King Saud Street have a cycle length of 180 seconds where as intersection connecting King Abdul Aziz Street has a cycle length of 90 seconds.

To build a VISSIM simulation model for this network and to calibrate it for the local traffic conditions, two types of data were required. The first type was the basic input data used for network coding of the simulation model and the second type was the field observation data employed for the calibration of simulation model parameters. Basic input data included data of network geometry, traffic volume data, turning movements, vehicle characteristics, travel demands, vehicle mix, stop signs, traffic control systems, etc. The coded VISSIM simulation network need to be further calibrated to replicate the local traffic conditions. The calibration involves comparing the simulation results against field observed data and adjusting model parameters until the model results fall within an acceptable range of convergence. Data collected for model calibration included traffic volume data, travel time, maximum queue length, average queue length and average link speed. In collecting all these data standard procedure were followed.

About 25 M.S. students studying in KFUPM were employed to smoothly conduct this data collection task. All these students had previous experience in collecting traffic data and in addition to it they were all extensively trained to collect the data needed in this study. In both the cities data were collected between 3:45 pm and 4:45 pm, it was not a study requirement but it's a coincidence. All the data needed for this study such as traffic volume, average travel time, average link speed and average and maximum queue length from both the networks were collected during this one hour period to avoid any form of inconsistency in comparing these data to the model simulation output. Street networks are created in VISSIM through a series of links and connectors. Base maps in a bit map format were imported and used to exactly trace a network in VISSIM.

A series of simulation runs were conducted to determine if the model is functioning as intended. VISSIM allow on-line viewing of the simulation runs. These verification runs revealed network coding errors such as lack of right turns on red, excessive speeds around corners, and lack of connection between links. Since VISSIM is a stochastic simulation model, it rely upon random seed numbers to release vehicles, assign vehicle type, select their destination and their route, and to determine their behaviors as the vehicles move through the network. Therefore, multiple simulation runs using different seed numbers were required and the average results of these several simulation runs reflected the average traffic condition of a specific scenario. A typical VISSIM run of the existing conditions model used for this study took an average 20 to 30 minutes to simulate a 1 hour and 15 minute simulation. The first 15 minutes were used to initialize the model. Statistics were gathered for the VISSIM runs only after the initial 15-minute period had elapsed.

With regards to calibration, traffic simulation model VISSIM contains numerous variables that represent the driving behavior characteristics in the country where the model is originally introduced and calibrated. Calibration is the process by which the individual components of the simulation model are refined and adjusted so that the simulation model accurately represents field measured or observed traffic conditions. Considering all these parameters for calibration was tedious job. Therefore, parameters which shown little or no affective such as vehicle acceleration and deceleration, etc., were disregarded because the vehicle type, vehicle class and vehicle model used in Saudi Arabia are same as that used in VISSIM model. More emphasize was done on the parameters which deals with the driving behavior such as number of observed vehicles, additive and multiplicative part of desired safety distance, amber signal decision model and distance required in changing lane

Typical traffic flow characteristics that were used in validation are average travel time, average link speed, average queue length and maximum queue length. The validation guidelines considered for this study was from the Caltrans agency. An initial simulation experiment was run on the network of Dhahran Street using default driving behavior parameters values and they were compared with the field observed average travel time, average link speed, and average and maximum queue length. It was found that none of the performance measure was matched with the field observed MOE’s except the average queue length; this is because the validation criterion is broad enough for this MOE which ranges up to 20%. Therefore the model was calibrated in an iterative process to decrease the discrepancy between calculated and observed measures of effectiveness until we reached convergence. From the simulation results of different trials of parameters a set was found to be best matching with the field observed MOE's.

The next step was to check the validity of these set of calibrated values by implementing them on another network which is chosen in Dammam. The model validation was proposed to conduct using a different data set of another network in Dammam city to check if the calibrated model parameters are suitable or not. Model validation was regarded as a final stage to investigate if each component adequately reproduces observed travel characteristics and overall performance of the model is reasonable. From the comparison of the field observed measures of effectiveness and simulation results of this Dammam network with the set of calibrated values it was clearly found that these set of calibrated values are very well satisfied the validation criteria. Hence it can be said that with these calibrated values VISSIM simulation model is fully suitable to the present and future traffic conditions of Saudi Arabia.

## 7.2 Conclusions

The main conclusions of this study are summarized in the following points:

- Based on the literature review, effectively identified the similarities and differences in traffic characteristics and driving behavior on urban networks between the Germany and Saudi Arabia.

- The parametric analysis was performed on the VISSIM Simulation Model and determined the variables that need to be modified to calibrate the model for the study area traffic conditions.

- Calibrated the VISSIM Simulation Model to replicate the local traffic conditions of Khobar and Dammam, Saudi Arabia and it is concluded that with few and well reasoned modification to its driver behavior parameters, the simulation model is capable of reproducing the field observed responses.

- The final task of validation of VISSIM Simulation Model was performed by implementing the calibrated variables on another arterial situated in Dammam and the obtained simulated results are found to be well satisfactory with the validation criteria given by the California transportation department (Caltrans).

## 7.3 Research Findings

Finally the practical conclusions of this research's findings can be summarized as the following points:

- Traffic simulation is a powerful and cost-efficient tool for traffic planning and designing, testing different alternatives and evaluating traffic management schemes.

- Based on the conducted literature review it was found that the VISSIM model is the most appropriate simulation model that was used extensively and successfully in many countries under various traffic conditions and driving behaviors. In addition to this, VISSIM is used for the evaluation of various alternatives and it offers excellent modeling of complicated networks and superior graphics.

- Since VISSIM uses links and connectors to construct both links and intersections it permits VISSIM to be very flexible when working with complex geometries. Working with the VISSIM model in this study it can be said that the model is flexible, easy to use, helpful to traffic engineers in Saudi Arabia, and can be applied to any network configuration in Saudi Arabia.

- Two study networks one for calibration in Khobar city and another for validation in Dammam city were selected successfully satisfying the criteria of common cycle length or multiple of common cycle length.

- The most important and hard-hitting task of data collection; traffic volume, average travel time, average travel speed, saturation flow, desired speed, average and maximum queue length, for study was conducted successfully within the time restrained of one hour.

- In VISSIM, the creation of street networks is fairly simple through the use of a graphical interface and an aerial photograph in the background.

- Although coding in VISSIM is time consuming, it was the most appropriate simulation tool to use for any kind of analysis because of capabilities not found in other simulation software.

- Calibration of the VISSIM model was carried out successfully based on the field observations. As a conclusion this study has shown that the VISSIM simulation environment is well-suited for such urban traffic situations involving complex interactions.

- Both calibration and validation results show that simulation tool VISSIM can reproduce traffic flow very realistically under real world conditions. Therefore it is promising to adapt the VISSIM model to the local traffic situation; at least national traffic regulations and driving styles must be taken into account.

# APPENDICES

# APPENDIX A

**Table A.1: Turning movement count at Dhahran St and Makkah St Intersection**

**Dhahran St. and Makkah St Intersection Traffic Volume Study**

| | **From North** | | | | **From East (from Khobar)** | | | | **From South** | | | | **From West (from Dhahran)** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Start Time** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** |
| 3:45 - 4:00 | 95 | 125 | 85 | 305 | 36 | 574 | 21 | 631 | 63 | 60 | 22 | 145 | 233 | 570 | 70 | 873 |
| 4:00 - 4:15 | 106 | 115 | 80 | 301 | 87 | 503 | 30 | 620 | 145 | 90 | 25 | 260 | 152 | 689 | 69 | 910 |
| 4:15 - 4:30 | 96 | 102 | 94 | 292 | 110 | 612 | 15 | 737 | 157 | 126 | 39 | 322 | 133 | 669 | 69 | 871 |
| 4:30 - 4:45 | 60 | 64 | 100 | 224 | 114 | 691 | 22 | 827 | 202 | 116 | 11 | 329 | 88 | 429 | 52 | 569 |
| Total | 357 | 406 | 359 | 1122 | 347 | 2380 | 88 | 2815 | 567 | 392 | 97 | 1056 | 606 | 2357 | 260 | 3223 |

**Table A.2: Turning movement count at Dhahran St and Prince Hamoud St Intersection**

**Dhahran St. and Prince Hamoud St Intersection Traffic Volume Study**

| | **From North** | | | | **From East (from Khobar)** | | | | **From South** | | | | **From West (from Dhahran)** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Start Time** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** |
| 3:45 - 4:00 | 50 | 117 | 53 | 220 | 33 | 392 | 65 | 490 | 99 | 143 | 14 | 256 | 130 | 501 | 100 | 731 |
| 4:00 - 4:15 | 50 | 103 | 44 | 197 | 20 | 392 | 94 | 506 | 113 | 130 | 22 | 265 | 110 | 460 | 90 | 660 |
| 4:15 - 4:30 | 82 | 109 | 59 | 250 | 19 | 378 | 99 | 496 | 94 | 134 | 25 | 253 | 130 | 572 | 80 | 782 |
| 4:30 - 4:45 | 50 | 100 | 77 | 227 | 29 | 384 | 132 | 545 | 129 | 128 | 24 | 281 | 125 | 559 | 60 | 744 |
| Total | 232 | 429 | 233 | 894 | 101 | 1546 | 390 | 2037 | 435 | 535 | 85 | 1055 | 495 | 2092 | 330 | 2917 |

**Table A.3: Turning movement count at Dhahran St and King Abdul Aziz St Intersection**

**Dhahran St. and King Abdul Aziz St Intersection Traffic Volume Study**

| | **From North** | | | | **From East (from Khobar)** | | | | **From South** | | | | **From West (from Dhahran)** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Start Time** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** |
| 3:45 - 4:00 | 93 | 121 | 168 | 382 | 153 | 292 | 50 | 495 | 146 | 173 | 15 | 334 | 169 | 240 | 74 | 483 |
| 4:00 - 4:15 | 102 | 168 | 159 | 429 | 161 | 299 | 61 | 521 | 98 | 241 | 13 | 352 | 172 | 255 | 121 | 548 |
| 4:15 - 4:30 | 121 | 199 | 155 | 475 | 173 | 319 | 47 | 539 | 160 | 181 | 12 | 353 | 165 | 261 | 130 | 556 |
| 4:30 - 4:45 | 163 | 232 | 177 | 572 | 205 | 323 | 70 | 598 | 115 | 221 | 13 | 349 | 170 | 250 | 107 | 527 |
| Total | 479 | 720 | 659 | 1858 | 692 | 1233 | 228 | 2153 | 519 | 816 | 53 | 1388 | 676 | 1006 | 432 | 2114 |

**Table A.4: Turning movement count at Dhahran St and Prince Maqrin St Intersection**

**Dhahan St. and Prince Maqrin St Intersection Traffic**

| **Start Time** | **From North (from Maqrin)** | | | **From East (Khobar to** | | | **From South** | | | **From West (from** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Left | Thru | Right | Left | Thru | Right | | | | | | |
| 3:45 - 4:00 | | | 48 | | | 24 | | | | | | |
| 4:00 - 4:15 | | | 45 | | | 20 | | | | | | |
| 4:15 - 4:30 | | | 48 | | | 22 | | | | | | |
| 4:30 - 4:45 | | | 52 | | | 25 | | | | | | |
| Total | | | 193 | | | 91 | | | | | | |

**Table A.5: Turning movement count at 1st St. and King Khalid bin Abdul Aziz St Intersection**

**1st St. and King Khalid bin Abdul Aziz St Intersection Traffic Volume Study**

| | From North | | | | From East | | | | From South | | | | From West | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Start Time** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** |
| 3:45 - 4:00 | 103 | 332 | 34 | 469 | 62 | 86 | 32 | 180 | 81 | 210 | 16 | 307 | 51 | 107 | 37 | 195 |
| 4:00 - 4:15 | 98 | 341 | 36 | 475 | 68 | 80 | 30 | 178 | 73 | 214 | 16 | 303 | 55 | 103 | 33 | 191 |
| 4:15 - 4:30 | 105 | 338 | 35 | 478 | 74 | 92 | 32 | 198 | 77 | 207 | 14 | 298 | 48 | 109 | 41 | 198 |
| 4:30 - 4:45 | 99 | 319 | 34 | 452 | 63 | 82 | 26 | 171 | 79 | 212 | 15 | 306 | 60 | 99 | 35 | 194 |
| Total | 405 | 1330 | 139 | 1874 | 267 | 340 | 120 | 727 | 310 | 843 | 61 | 1214 | 214 | 418 | 146 | 778 |

**Table A.6: Turning movement count at 1st St. and King Saud bin Abdul Aziz St Intersection**

**1st St. and King Saud bin Abdul Aziz St Intersection Traffic Volume Study**

| | From North | | | | From East | | | | From South | | | | From West | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Start Time** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** |
| 3:45 - 4:00 | 68 | 295 | 76 | 439 | 39 | 99 | 42 | 180 | 71 | 196 | 29 | 296 | 79 | 142 | 29 | 250 |
| 4:00 - 4:15 | 64 | 296 | 76 | 436 | 45 | 100 | 39 | 184 | 74 | 189 | 32 | 295 | 71 | 138 | 26 | 235 |
| 4:15 - 4:30 | 67 | 296 | 80 | 443 | 46 | 97 | 51 | 194 | 70 | 208 | 27 | 305 | 77 | 149 | 21 | 247 |
| 4:30 - 4:45 | 73 | 295 | 73 | 441 | 43 | 93 | 40 | 176 | 77 | 198 | 26 | 301 | 74 | 140 | 33 | 247 |
| Total | 272 | 1182 | 305 | 1759 | 173 | 389 | 172 | 734 | 292 | 791 | 114 | 1197 | 301 | 569 | 109 | 979 |

## Table A.7: Turning movement count at 1st St. and King Abdul Aziz St Intersection

**1st St. and King Abdul Aziz St Intersection Traffic Volume Study**

| | **From North** | | | | **From East** | | | | **From South** | | | | **From West** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Start Time** | U Turn | Thru | Right | **Total** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** | Left | Thru | Right | **Total** |
| 3:45 - 4:00 | 41 | 300 | 105 | 446 | 0 | 0 | 0 | 0 | 193 | 129 | 0 | 322 | 125 | 0 | 130 | 255 |
| 4:00 - 4:15 | 42 | 289 | 101 | 432 | 0 | 0 | 0 | 0 | 206 | 127 | 0 | 333 | 121 | 0 | 118 | 239 |
| 4:15 - 4:30 | 46 | 294 | 93 | 433 | 0 | 0 | 0 | 0 | 202 | 132 | 0 | 334 | 140 | 0 | 124 | 264 |
| 4:30 - 4:45 | 48 | 306 | 99 | 453 | 0 | 0 | 0 | 0 | 208 | 125 | 0 | 333 | 148 | 0 | 122 | 270 |
| Total | 177 | 1189 | 398 | 1764 | 0 | 0 | 0 | 0 | 809 | 513 | 0 | 1322 | 534 | 0 | 494 | 1028 |

# APPENDIX B

## Saturation Flow Study

**Table B.8: Saturation Flow Study**

| Observation No. | Time (seconds) between 4th vehicle and …. | | | |
|---|---|---|---|---|
| | 7th veh | 8th veh | 9th veh | 10th veh |
| 1 | | 7.31 | | |
| 2 | | 7.26 | | |
| 3 | 5.56 | | | |
| 4 | 6.11 | | | |
| 5 | 6.25 | | | |
| 6 | 5.48 | | | |
| 7 | | | 8.71 | |
| 8 | 5.81 | | | |
| 9 | | | | 10.32 |
| 10 | 5.47 | | | |
| 11 | | 8.05 | | |
| 12 | 5.28 | | | |
| 13 | | | | 10.1 |
| 14 | 6.32 | | | |
| 15 | | 8.11 | | |
| 16 | 5.65 | | | |
| 17 | 6.12 | | | |
| 18 | 5.48 | | | |
| 19 | | | 8.86 | |
| 20 | | | | 11.08 |
| 21 | 6.02 | | | |

| | | | | |
|---|---|---|---|---|
| 22 | | 6.22 | | |
| 23 | | 6.96 | | |
| 24 | | | | 11.23 |
| 25 | 5.89 | | | |
| 26 | | 7.56 | | |
| 27 | 5.45 | | | |
| 28 | | | 8.58 | |
| 29 | | 7.24 | | |
| 30 | 5.86 | | | |
| 31 | 5.54 | | | |
| 32 | | | 8.34 | |
| 33 | 6.12 | | | |
| 34 | 6.38 | | | |
| 35 | 5.76 | | | |
| 36 | | 6.68 | | |
| 37 | | 7.46 | | |
| 38 | 6.26 | | | |
| 39 | 5.34 | | | |
| 40 | 5.64 | | | |
| Sums | a=127.79 | b=72.85 | c=34.49 | d=42.73 |

| | | | | |
|---|---|---|---|---|
| a/3 + | b/4 + | c/5 + | d/6 | |
| 42.59667 | +18.2125 | + 6.898 | +7.121667 | =74.82883 |

Mean Saturation Flow (vphpl) = 3600*40/74.82883 = 1924.392

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